

# **HISTORY OF AVIATION AND COSMONAUTICS**

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**N. D. Anoshchenko (Ed.)**

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## EDITORIAL NOTE

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In 1964, the Executive Committee of the Aviation Section of the Soviet National Association of Historians of Natural Science and Technology commenced publication of the thematic collections entitled "Pages from the History of Aviation and Cosmonautics", in which papers presented at the Sessions of the Section will be published.

These collections will be published by the All-Union Institute of Scientific and Technological Information (VINITI) in separate issues. The papers will be published by the offset printing method, together with news items, on the work of the Section and its groups.

This publication is designed for specialists in the field of aviation and rocket technology, and for the general public interested in the history of aviation and cosmonautics.

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\* Numbers in the margin indicate pagination in the foreign text.

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## HISTORY OF AVIATION AND COSMONAUTICS

### IN MEMORIAM SERGEY GRIGOR'YEVICH KOZLOV



ABSTRACT. The history of aviation in the USSR, specifically in the rocket field, is reviewed from a personal viewpoint of national achievement. Separate papers are included on first rocket plane flights, achievements of the Leningrad Jet Propulsion Study Group and biographies of Russian aircraft designers. Details are given on construction, launch characteristics, altitude behavior, and propellant composition of illuminating rockets, aerophotosurvey rockets, atmospheric sounding rockets, and other experimental rockets for which dimensions, weight, maximum altitude, thrust, and other characteristics are tabulated.

The USSR is rich in talented people. One of these geniuses was Professor Sergey Grigor'yevich Kozlov, a prominent worker in the science of aviation. He was an unusually gifted person, an outstanding teacher, an excellent designer, a thoughtful research worker, the author of a number of extremely interesting scientific works, the educator of a whole generation of aviation engineers, and

the mentor for many fledgling scientists. I should like to write in detail about this remarkable man: how he lived, struggled, learned, and taught others, but /5 this would be a long story rather than a brief article.

S.G.Kozlov was born on September 22, 1894 in the city of Volokolamsk, Moscow Oblast'. His father, Grigoriy Ivanovich, was a high school music teacher.

Sergey Grigor'yevich started his studies at a parochial school, then at a preparatory school, and later switched to a theological institute and seminary. This course of study was dictated by the straitened circumstances of the Kozlov family. They could not afford to pay Sergey's tuition fees, while tuition was gratuitous at the preparatory school and the seminary.

However, it was difficult for the impetuous youth, labile as quicksilver, to endure this study in the stagnant atmosphere of the seminary, a school for training clergymen. He left the seminary and began to study at home. His great abilities made it easy for him to prepare himself for the out-student examination for graduation diploma and to pass that examination.

In Autumn, 1913, Sergey entered the Imperial Moscow Polytechnic Institute (IMTU, now the MVTU imeni Bauman) where he met Professor N.Ye.Zhukovskiy, the famous Russian scientist - a meeting that was destined to determine the whole course of Sergey Kozlov's life.

Zhukovskiy was the father of Russian aviation. That name, even today, still glows in an aureole of immortal glory. To the students of those years it was the symbol of progressive science, a banner calling to scientific advance.

"Man has no wings and, in the ratio of muscle weight to body weight, is 72 times weaker than a bird... Yet I think that he will begin to fly, relying not on the strength of his muscles but on the power of his mind". These proud words by Zhukovskiy were imprinted in letters of fire on Sergey Kozlov's brain. His active nature called for knowledge, for heroic deeds.

Ever since those days, S.G.Kozlov was inseparably connected with aviation and aviation science. N.Ye.Zhukovskiy's lectures, the studies under his guidance at the theoretical aviation courses of the IMTU, and the personal contacts with the renowned scientist, helped Sergey Kozlov to find a fitting outlet for his outstanding abilities, perseverance, and love of work.

However, the war interrupted his studies, and we see S.G.Kozlov next at the Kachinsk School for Military Aviators, then at the Naval Aviators' School at Petrograd and Baku. It was not easy for him to study at these schools, first as an enlisted man and then as a common sailor, since most of the others were officers. The knowledge acquired at the IMTU under the influence of Zhukovskiy /6 helped Sergey Kozlov immensely here. It gave the slender small-stature buck private unquestionable authority with the airforce rookies, while his excellent performance of training flights put him in the top bracket as to rate of progress.

After the February Revolution, S.G.Kozlov was commissioned an officer and stationed for service on Oesel Island in the Baltic Sea. The difficult and dangerous tasks of a naval aviator commenced. He eagerly learned to fly the

famous M-9 hydroplanes of our famous designer D.P.Grigorovich.

Came the October Revolution: Brigadier S.G.Kozlov, of the Brigitovkoy Hydro-aviation Station, volunteered for service in the Red Navy in November 1917.

During the strenuous years of the Civil War, S.G.Kozlov fought against the White forces of Denikin, Yudenich, and Wrangel. On worn-out, obsolete aircraft he fought the White Guard pilots on up-to-date British and French machines supplied by the "Allies" to the White Guard Armies.

In 1919, S.G.Kozlov became Chief of the Air Division of the famous Volga-Caspian Flotilla. On one of his flights on a decrepit Nieuport-17, though wounded in the right hand and with the aircraft riddled by bullets, S.G.Kozlov still carried out a highly important reconnaissance of enemy artillery positions. For this exploit, he was given the Order of the Red Banner.

Thus, Sergey Kozlov's scientific career in aviation did not begin in the lecture-hall before the blackboard and not in the aerodynamic laboratory, but in the pilot's seat of a fighter plane, riddled by enemy bullets, fighting to the end with the White Guards, and winning a shining future with his very blood.

After the victorious conclusion of the Civil War, S.G.Kozlov resumed his education. In October 1921, he enrolled at the Institute of Engineers of the Red Air Force, renamed the Academy of the Air Force of the Red Army in 1922. S.G.Kozlov graduated from that Academy ahead of time in 1923 and commenced his work as a scientist and teacher. He gave exercises to the students of the Academy, wrote scientific papers and textbooks, invented, occupied himself with music, and did a large amount of social work. Avidly he plunged into the atmosphere of creative activity. Here his talents as a scientist broadened ever more.

The area of S.G.Kozlov's scientific interests covered an unusually wide 17 range. He lectured on propellers, supervised the computation and design office of the Academy, conducted in-course and diploma projects on propellers and hydroplanes, and designed an anemometry station. In 1935, he became Chief of the Department of Aircraft Structure and Strength. His papers were published in rapid succession - technical study of the semisubmerged propeller; design for a hollow Dural propeller (1924); nomographic method for aerodynamic aircraft calculation; aerodynamic propeller calculations; aerodynamic calculation of biplane fuselages (1927); selection of propeller and plotting of characteristics of propeller-engine systems; aerodynamic calculation of aircraft by the rpm method (1931); calculation of seaplane floats, and innumerable others.

It is impossible here to give even a brief outline of these papers. However, we must not fail to say a few words about two of them.

In 1927, S.G.Kozlov published an original method of aerodynamic calculation of the biplane fuselage. This simple and elegant graphoanalytic method, which came to replace the method of the German investigator Betz, permitted - under certain simplifying assumptions - a graphic solution of equations correlating coefficient of lift and angle of attack.

The simplicity and lucidity of this calculation method set it apart from all earlier methods, but furnished an entirely acceptable degree of accuracy. It found widespread use in the USSR and abroad.

Another very interesting study by S.G.Kozlov concerned the development of an aerodynamic method of calculating an aircraft by the graphoanalytic rpm method.

This method was developed by S.G.Kozlov in 1931, in collaboration with the famous Professor V.S.Pyshnov. The methods of aerodynamic calculation in use until 1931 were applicable only over tedious and time-consuming calculations to direct comparisons of the results of flight tests with the results of aerodynamic calculations.

The rpm method was free of this shortcoming and, immediately after publication, came into extensive use for calculating aircraft with piston engines and constant-pitch propellers. Much later, after the appearance of jet aircraft, a modernized rpm method was used in processing data for turbojet aircraft. /8

During the same years, S.G.Kozlov designed a propeller of magnesium alloy, special skids for aircraft, a tailless aircraft, an "invisible" aircraft, and a number of other objects.

In 1939, S.G.Kozlov was admitted to membership in the USSR Communist Party. He continued his work with still greater energy. He wrote a number of textbooks, designed interesting aircraft, revised a few previously published papers, and supplemented them by new material.

S.G.Kozlov did not confine himself to purely aviation subject matters. His inquisitive mind and his thirst for research induced him to solve the most varied problems. For example, he made an exact calculation of the strength of a bicycle wheel, a detailed calculation of the violin bow, and an acoustic calculation of the violin resonance box.

Music played a major role in Kozlov's life. He was a talented musician and played many musical instruments, including the violin, the viola, the violoncello, the flute, and a number of other wind instruments. Music was his favorite relaxation from scientific work and teaching. He took pleasure in performing in various musical ensembles, trios or quartets, and had a large musical library at home. Sergey Kozlov particularly loved Russian music with which he was well acquainted.

S.G.Kozlov was a skillful teacher. Working in the field of higher education, he made a profound study of the pedagogical views and the teaching experience of famous Russian pedagogues - Mendeleyev, Timiryazev, Zhukovskiy, and many others. Based on his study of this experience, he developed his own original methods of instruction. He prepared interesting lectures. One would think that, after giving the same course over and over again for many years, he would no longer have to take much trouble in preparing each lecture. Nevertheless, each lecture Kozlov gave was as though he were delivering it for the first time. With great agitation, carefully selecting every adjective, he would build up his phrases, frequently making sketches on sheets of paper, demonstrating how they

would look on the blackboard. Later on, he began to film a series of graphic material for each lecture, so as to illustrate his lectures without losing time on drawing. To avoid distracting his listeners by having them copy these materials, Kozlov had them mimeographed in advance, and passed out folders containing the copies.

In contrast to many instructors who give a purely descriptive course in aircraft structure, Kozlov strove to give his course on a high theoretical level, so as to impart some idea on the replacement of a given technical solution /9 by some other more advanced solution.

S.G.Kozlov built up his lectures so as to provide an exposition, in elegant mathematical form, of all the generalizations and laws he tried to confer to his listeners. Himself a good mathematician, he knew how to represent even complex concepts by relatively simple systems of equations, readily mastered by his students. This very same feature is also characteristic of his papers. Profound thoughts and sweeping generalizations are expressed in a relatively simple mathematical form.

The many years of study of the development of aircraft construction naturally led Kozlov to formulate a number of laws underlying this development. So it was that he became interested in the history of aircraft and the history of aviation engineering. This interest was furthered by the fact that he had come into contact with aviation in his early youth, that the entire development of aviation had unfolded before his very eyes, and that he had been not merely a witness but an active participant in that development. For this reason, when Kozlov's health compelled him to give up his strenuous teaching activities and he suddenly had leisure time, a luxury unheard of before then, he began seriously to concern himself with the history of aviation engineering. To this task, Kozlov brought his characteristically methodical habits and his scientific conscientiousness. After many years of work in aviation and aviation science, he had formed many ties with a large number of specialists. Contact with them had enriched his mind with much interesting information, pertinent figures, and observations on the history of aviation in the Fatherland.

As he collected such materials and as his files bulged with memos and notes, Sergey Kozlov began to understand with increasing discernment that the coordinated work of a large number of experts was a prerequisite for fruitful work on the history of aviation engineering. These thoughts and considerations led him to the Institute of the History of Natural Science and Technology of the USSR Academy of Sciences, where he soon became the director of the Section of the History of Aviation Science and Engineering of the Soviet National Association of Historians of Natural Science and Technology.

Soon he recruited for this Section a large group of specialists, many of whom had been prominent participants in establishing the mighty Soviet aviation. At numerous sessions of the Section, interesting papers were presented on various problems of the history of aviation engineering. Skillfully guiding the /10 work of the Section, he had soon established a base for spelling out the fundamental work on the history of aviation engineering.

Death prevented him from crowning his career with the completion of this

task. The duty of his colleagues in this work is to complete what he commenced.

Being a man of sweeping erudition and a thoughtful investigator, Sergey Grigor'yevich Kozlov was an irreplaceable consultant on the most varied branches of science and technology. During the last years of his life, he performed much fruitful work as a member of the Council of Experts of the USSR Patent Office. His participation in this work contributed to the correct solution of highly complex and controversial questions.

Many inventors whose ideas he instilled with life will remember with gratitude the attentive rigorous and sensitive specialist who deeply studied the gist of the questions and expertly threaded his way through the most tangled matters.

The high qualifications of this remarkable Communist scientist manifested themselves in full measure in this complex work: immense erudition, sensitivity to the new, objectivity in evaluating facts and events.

May the shining memory of Sergey Grigor'yevich Kozlov live long in the hearts of his friends and comrades.

V.A.Popov

# THE FIRST USSR ROCKET PLANE FLIGHTS

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I.A.Merkulov

Over forty years ago, F.A.Tsander, one of the Pioneers of Soviet rocket building, prepared plans for an interplanetary ship using wings for motion in the atmosphere. He saw in the construction of winged rockets one of the keys of mastery of outer space.

The GIRD leaders had a high appreciation for Tsander's ideas, and from the very beginning the problem of winged rockets was on their list of major themes. One of the four GIRD teams concentrated their efforts on this exceptionally promising and yet highly complex problem.

The experimental rocket plane GIRD-RP-I was built in 1932 from plans by B.I.Chernanovskiy. It was a tailless aircraft of wooden construction. Its technical data are interesting. The wing span was 12.1 m, the wing area 20 m<sup>2</sup>. The aircraft was 3.09 m in length and 1.25 m in height. The weight of the aircraft, without the engine, was only 200 kg. The aircraft had good dynamic data, its aerodynamic effectiveness (lift/drag ratio) was 16. The plans were to install the liquid-propellant rocket engine OR-2 of Tsander's design, burning gasoline and liquid oxygen, on the rocket plane. The engine was placed aft of the cockpit, and the fuel tanks - one for gasoline and two for oxygen - together with the cylinder of compressed nitrogen, in the wing center section.

The following are the design performance data of the rocket plane GIRD-RP-I:

	At Engine Thrust of	
	50 kg	100 kg
Takeoff time, sec .....	60	20
Rate of climb at sea level, m/sec ....	2.2	7.1
Maximum ground speed, km/hr .....	139	198
Ceiling, m .....	810	1400
Fuel consumption, gm/sec .....	250	420
Endurance, min .....	6	4
Flying range, km .....	13	20

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The rocket aircraft GIRD-RP-I entered its first stage of flight tests during which the crew flew the airframe (without the liquid rocket engine).

The next winged rocket flying machine to be built was a winged rocket. The preliminary work was started by the GIRD and was completed at the Jet Research Institute. On this rocket, a liquid rocket engine, using alcohol and liquid oxygen, was installed in its tail section. Its first flight was made on May 23, 1934.

Work to improve the winged rocket was continued during the following years. The engine ORM-65, burning kerosene and nitric acid and built in 1936, was in-

stalled on it. The data of this rocket, factory number 212, were as follows:

Construction of rocket	.....	all-metal
Length	.....	3.16 m
Span	.....	3.06 m
Flying weight	.....	210 kg
Weight of propellant	.....	30 kg.

The rocket was provided with gyro-stabilization and automatic pilot systems. Its ORM-65 engine developed a maximum thrust of 175 kg. The rated thrust was 150 kg and the minimum thrust, 50 kg. Under rated conditions, the specific thrust was 210 sec at a pressure of 23 atm abs in the chamber. The engine could be started manually or automatically.

The ORM-65 engines withstood numerous starts. ORM-65 No.1 after 49 starts operated 30.7 min on the ground: 20 starts on the test stand, 8 starts on the winged rocket 212, and 21 starts on the rocket plane RP-318. The ORM-65 No.2 made 16 starts: 5 on the winged rocket 212 and 9 on the rocket plane RP-318.

From April 29, 1937 to October 20, 1938, ground firing tests were performed with the engine ORM-65 with an automatic starting system. On January 29 and March 8, 1938, flight tests of the winged rocket 212 were carried out. The log shows that starting and operating data of an ORM-65 engine which had made two 13 flights were satisfactory. The rocket was launched by the aid of a solid-propellant launcher.

In 1940, the first USSR manned flights on an aircraft with a liquid-propellant rocket engine took place. These historic flights were performed by the pilot V.K.Fedorov. A large amount of preparatory work preceded the flight tests.

The flights were made on a rocket plane RP-318, based on the glider SK-9. The technical data of this rocket plane were as follows:

Technical Data of Rocket Plane RP-318-1 with Engine ORM-65

Construction of rocket plane	.....	wooden monoplane
Length	.....	7.44 m
Span	.....	17 m
Takeoff weight	.....	700 kg
Propellant supply	.....	75 kg
Engine operating time	.....	100 sec
Thrust	.....	150 kg.

The engine was installed in the tail of the fuselage.

The first ground firing test of the rocket plane took place on December 16, 1937. During this test, the engine operated for 92.5 sec. During the following 26 days it was started successfully 20 times more, with as many as five starts in a single day, for instance, on January 11, 1938.

After protective maintenance of the rocket plane, the firing tests were continued, and between February 3 and April 15, 1938, a total of nine starts were made with a maximum continuous operation of 230 sec (March 11, 1938).

Thus the rocket plane RP-318, already at the beginning of 1938, was completely prepared for the flight tests. For organizational reasons, however, the tests themselves took place only two years later. During this time, the engine designed for the rocket plane was modified, and in October 1939 it was overhauled and successful ground firing tests of the rocket plane RP-318 were made with the modified engine. It was then decided to make the flight tests. For a more complete test of engine operation in the air and for extending the flight as much as possible, the plane was towed by a conventional aircraft to an altitude of 2 km. At this altitude, the pilot Fedorov released the tow line and changed to independent flight. Flying at a sufficient distance from the tow plane, Fedorov cut in the engine. It continued to operate until the propellant had been completely consumed. At the end of powered flight, the pilot successfully volplaned to the airfield.

The first flight of V.K.Fedorov on the rocket plane RP-318 was accomplished on February 20, 1940.

In 1941, the designer V.F.Bolkhovitinov designed a rocket fighter aircraft with an engine by L.S.Dushkin.

The Bolkhovitinov aircraft was a cantilever midwing monoplane of mixed construction with retractible landing gear. The nose of the fuselage carried two 20 mm cannon, ammunition, and a radio. Aft of this compartment was the pilot cockpit, covered with a canopy, and the fuel-tank compartment. The tail of the fuselage housed a liquid rocket engine.

Flight tests of the new aircraft were commenced in September 1941. At first, the aerodynamic properties of the aircraft itself were tested, without starting the engine. For this, the plane was towed into the air by a Pe-2 bomber.

On May 15, 1942 the test pilot G.Ya.Bakhchivandzhi made the first flight with the engine operating. Under the thrust of the engine, the aircraft took off from the airfield rapidly reaching a high altitude. Bakhchivandzhi made a smooth landing after flying his assigned route. Subsequently, other pilots made flights on this rocket fighter.

During World War II, Soviet aircraft designers worked on several other types of fighters with liquid rocket engines.

Thus Soviet designers and test pilots opened a new era in the history of our rocket engineering, the era of manned flights on winged rocket flying machines.

ON THE 75<sup>th</sup> ANNIVERSARY OF THE BIRTH OF THE AIRCRAFT  
DESIGNER K.A.KALININ

/15

V.B.Shavrov

Konstantin Alekseyevich Kalinin (1889-1938), military pilot since 1916 and engineer since 1925 (graduated from the Kiev Polytechnic Institute), was one of the most famous of our aircraft designers from 1925 to 1937. He designed 16 aircraft types and their modifications, bearing designations from K-1 to K-13. His aircraft were extensively used in our civil aviation and, before the war, were more numerous than all other types of passenger aircraft.

He commenced his career in the Ukraine. K.A.Kalinin was sponsored by government circles and the public of the Ukraine. A production base was established for him; young engineers, graduates of Kharkov Aviation Institute, came to him. Designers such as I.G.Neman, A.Ya.Shcherbakov, Z.I.Itskovich, V.Ya. Krylov, P.G.Bening, A.A.Lazarev, and others began their careers under his tutelage.

K.A.Kalinin's aircraft had many features in common and often were original in configuration and construction. All were of the semi-cantilever or cantilever monoplane type, usually with a wing and horizontal tail surfaces of elliptic planform (a characteristic feature of Kalinin's aircraft). They were of mixed construction, the fuselage and vertical tail surfaces being invariably made of welded steel tubes, mostly with a fabric skin. The wings were usually of wood and likewise had a fabric skin. Nonferrous metals were used sparingly.

At that time wood, plywood, steel tubing and canvas were in relatively good supply. Structures built of such materials were simplest, cheapest, and most /16 easily repaired. This promoted widespread use of Kalinin's civilian aircraft, which were more economical than those of other designers, whether USSR or foreign.

Kalinin also designed military aircraft, which were highly individual in their features. From examples of these craft (K-7, K-12, and K-13), it is obvious that Kalinin was a bold designer and knew how to take technical risks to meet even the most difficult problems.

In 1920, after the end of the Civil War, workshops of the Kiev Airpark were established and placed in operation. In the Spring of 1921, military aircraft were repaired there. In 1923, a pioneer group, headed by Kalinin who was in charge of the design office there, was formed to design a passenger aircraft outside the conventional scope. He conceived the ingenious idea of using steel tubing salvaged from an obsolete "Voisin" aircraft. By the Summer of 1925, his passenger aircraft K-1 had been built.

The prototype was a semi-cantilever monoplane with a Salmson 170-hp engine. Its fuselage was welded of steel tubes, the first in the USSR, all of them trussed, without wire bracing. The pilot cockpit had a closed canopy (rare at

that time). The three-place passenger cockpit had a couch and two chairs.

On June 26, 1925 the K-1 made its maiden flight followed by a number of others; on September 17 it flew to Moscow by way of Kharkov, where, within two more weeks, its tests were completed. The aircraft was found to meet all requirements for a passenger aircraft and was rated for service in the Civil Air Fleet. It was admitted to series production. However, since the Salmson engine had already become obsolete, it was decided to replace it by the BMW-IV 240-hp engine which was then more practical, and to develop the aircraft further. This version was produced in the following year (1926), under the designation K-2.

/17



Konstantin Alekseyevich Kalinin  
1889-1938

The K-2 hardly differed in dimensions from the K-1 (except for the engine) but its construction was of the all-metal type, as an experiment. The fuselage was welded of tubes with a skin of thin Kol'chug aluminum alloy over the cockpits. The wing and tail surface framework were of the same material, with a fabric skin. The structure proved to be relatively heavy. Even more important

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than that, it was also expensive, and the all-metal idea was dropped. The K-2 did have better flight performance and had four passenger places instead of the three in the K-1.

In 1927, the K-3 was put into production with the same contours and the same engine but a different function. It was now to be used as an air ambulance for two patients on stretchers and a physician or for three sitting patients and a doctor. This was the first hospital-type aircraft in the USSR. The flying range was five hours instead of four in the earlier model. The stretchers were placed on special stands and supports, according to a system developed by Dr. A.F. Lingart (who might rightly be called the founder of medical aviation in the USSR). The stretchers were put on board through a horizontal door.

The K-3 was followed by the K-4 in 1928. There were almost no differences, except for the more refined design and thus somewhat lower weight, using the same BMV-IV engine and put out in three modifications as a passenger, aerial photographic survey, or hospital plane. The K-4 passenger plane had a fuel supply for six hours of flight. The aerial survey plane K-4 was fully equipped for surveys with one or two cameras, photographing through a special hatch in the floor of the cockpit. It carried a crew of three: pilot, navigator, and photographer. Work on the aircraft was very comfortable. It was widely used for aerial surveys in various parts of the USSR.

The air ambulance K-4 differed little from the K-3. One of them had a 300-hp M-6 engine and was exhibited at the International Air Show at Berlin in 1929. Several of these were successfully used in the medical evacuation service.

The K-4 was put into series production in 1930. In all, 22 units were built. The series was restricted to this number since the BMV-IV engine was not produced in the USSR. The demand for air travel increased, and in 1929 a ten-place K-5 was produced, replacing the earlier models on the airlines.

On the K-4 "Chervona Ukraina", a record flight was made in August 1928 by the pilot M.A. Snegirev and the navigator I.T. Spirin, over the route Kharkov - Moscow - Irkutsk - Moscow - Kharkov. The introduction of Kalinin passenger aircraft into operation on the airlines of the Ukraine, during the first stages, met considerable opposition from the management of Ukrvozdukhput', who gave preference (as it proved, an unfounded preference) to the German Dornier aircraft. Kalinin's merit was to build the first civilian aircraft ever manufactured in series production. /19

The K-5 aircraft was a modification of all the earlier aircraft from K-1 to K-4, with the same mixed construction of steel tubes, wood, and fabric, but wire trusses were used in the fuselage framework, thus decreasing its weight. Dural was used only in the skin of the fuselage nose, in the canopies, in the construction of the seats and in the cantilever fairings. The aircraft was inexpensive and economical; with a 450 to 480-hp engine it could carry eight passengers over 800 km at a speed of 160 - 170 km/hr. The K-5 was one of the most popular aircraft of our fleet in 1930 - 1941; it was produced in series from 1931 to 1934, first using 450-hp M-15 engines and later the 480-hp M-22 version. A total of 260 aircraft, operated on almost all our airlines, was produced.

By 1934, the performance of the K-5 had already become inadequate, and an attempt at improvement was made by installing a more powerful engine, the 680-hp M-17. The speed was increased but the payload had to be reduced, for structural strength considerations. Nevertheless, for several tens of series machines, this engine substitution was used.

In 1930, the K-6 aircraft was built. It had an M-22 engine and was a two-place postal plane used for transporting news mats. Its speed was 210 km/hr, but on the whole it differed little from the K-5 and was therefore not produced in series. The K-9 and K-10 were light aircraft. Both of them had folding wings (to facilitate hanging). They were not produced in series.

The K-7 was a giant aircraft. In dimensions and weight it was one of the largest in the world in those years. Seven 750-hp M-34 engines were installed on it. From a wing of elliptical planform and thick profile ran two tail booms of trihedral cross section and supporting the tail assembly. Under the wing, two heavy columns and eight separate outriggers carried large nacelles housing the landing-gear wheels and the gun emplacements. Inside the columns were hatches for entrance to the wing whose central portions were considerably thicker than the height of a man (2.2 m). The aircraft was intended as a heavy bomber, and also was produced in a passenger version with 120 passenger seats in the wing. These seats could be replaced by 64 berths in 16 compartments. The military version was planned to carry four cannon and eight machine guns at a large bomb load. /20

The body of the aircraft, its wing, its tail booms and almost all other parts, were welded of steel chrome-nickel tubes. The framework was made of tubes, with the skin partly fabric and partly dural. All parts had truss ribs, including the tail booms. The wings had four spars, with the center spars designed as double tubes. Six engines were installed in front of the wing leading edge, using tractor propellers. The seventh engine was mounted to the trailing edge of the wing between the tail booms, using pusher propeller. Unfortunately, the M-34 engine at that time still had no reduction gearing and was essentially unsuitable for a giant aircraft. The relatively small propellers swept an unusually thick wing, markedly impairing the efficiency. The gross weight of the aircraft was 40 tons.

Designing of the K-7 aircraft began as early as 1929, and the final plans were approved in 1931. On July 29, 1933 the aircraft was substantially finished in construction and was placed on the airfield.

The bombing equipment was not yet installed. The newspaper "Izvestiya VTsIK" sponsored the K-7, which was to be turned over later to the Intelligence Squadron, imeni Gor'kiy as its flagship.

The first flight took place on August 11. Over a period of two months, this was followed by nine more flights without incident, except that various unavoidable design and production defects were revealed that required elimination. On November 20, over a measured run, a speed of over 230 km/hr was attained. The aircraft passed almost all plant tests. Its eleventh flight, on November 21, ended in a catastrophe. Before going into its measured run at maximum horizontal speed, the aircraft unexpectedly began to lose altitude, /21

crashed to the ground, and burned.

The cause of the disaster was not established. Apparently, the servorudder and servoelevator, with their cable controls, whose dimensions exceeded the overall dimensions of the control surfaces, caused vibration of the tail assembly under certain operating conditions of the rear engine with its pusher propeller; in all probability, this was the cause of the failure and disaster. At that time, the problem of aircraft vibration had not yet been sufficiently investigated.

After the crash of the K-7, Kalinin designed other aircraft. At this period, his work mainly concerned the design of two original military aircraft, K-12 and K-13. However, the K-7 was by no means discarded. On demand by the management, two more K-7 were authorized, both with tetrahedral tail booms and a number of improvements; however, construction was stopped in 1935 when one of the prototypes had already been 60% completed.

The K-12 (or BS-2 "Firebird") was an experimental tailless aircraft with two 480-hp M-22 engines. It resembled the flying wing configuration on which K.A. Kalinin worked persistently, seeking ways to build a super-speed high-altitude aircraft, as a flying wing.

The K-12 had a normal trapezoidal wing, without sweepback but with considerable taper toward the tips on which wing-tip fins, known as wing disks, were installed. The wing profile was the well-known R-P type developed by P.P. Krasil'shchikov and still in use on many aircraft and gliders. In the K-12, however, the profile was very skillfully modified. Along almost the entire trailing edge of the wing there ran suspended flaps of the same R-P profile but inverted. If they had not been of the inverted type, the effect would not have been the same as that obtained by him. The outsides of the flaps functioned as ailerons, while the insides (close to the fuselage) operated as elevators or "elevons".

The design of the K-12 was commenced in 1934. It was a three-place bomber with front and rear shielded firing positions, with closed pilot cockpit and a bomb bay in the fuselage for 50 kg of bombs. To check the layout of the aircraft, an airframe geometrically similar but only half the size was built in 1934. This was used for almost a hundred flights, including aerobatics. The tests confirmed the correctness of the layout. /22

The construction of the aircraft, including its wing, was of welded chrome-nickel tubing, with a fabric skin using dural only for the surface of the pilot cockpit and the forward gun position. The aircraft contained no wood; it was decoratively painted with bright-red pictures of the "Firebird".

The aircraft was placed on the field in August 1936. The flight tests showed that a tailless aircraft could fly reliably and show good stability and controllability. Confidence in it was so great that it was shown in the Tushino air show of August 18, 1937. It was then returned to the plant and, after applying the finishing touches, was placed into series production. It was the first true tailless bomber in the world.

Almost simultaneously with the K-12, the K-13 was built and tested. This was a two-engine bomber with biplane tail assembly, although it was not as successful as the K-12. However, all work on both aircraft was suddenly stopped in Spring of 1938, since Kalinin, at the peak of his career, fell victim to the arbitrary and vicious procedures arising from Stalin's cult of personality. He did not reach the age of 50.

Today, a quarter of a century later, it is clear that K.A.Kalinin achieved almost everything that was practically possible in the field of medium civilian aircraft, characteristic of the period of the First Five-Year Plan. He had already passed to designing more complex and faster aircraft, but his ideas in this direction could not be realized.

FROM THE HISTORY OF THE LENINGRAD JET PROPULSION  
STUDY GROUP (LENGIRD)

123

V.V.Razumov

At the beginning of the 1930's, the Leningrad Oblast' Council of the OSOAVIAKhIM organized a jet propulsion study group, in the public domain, under the name of LENGIRD.

I had read books by K.E.Tsiolkovskiy and Professor N.A.Rynin on interplanetary travel, and had been visiting Professor Rynin repeatedly. We had long talks on interplanetary trips and rockets and, on my own initiative, with his council, I had done much work on preliminary sketches for a high-altitude rocket burning liquid propellant.

At that time, I was consultant to the Leningrad branch of the Dirigible Balloon Works, where I met the famous balloonist P.F.Fedoseyenko. Once, in a conversation with him, I told him that I was very much interested in rockets and that I had often met Rynin with whom I had discussed problems of interplanetary travel.

To my astonishment, Fedoseyenko reacted with great interest and stated that it was very timely and that, in fact, the Office of Aerial Technology of the Leningrad OSOAVIAKhIM was just then planning to organize a volunteer group to study and build rockets.

He suggested that I participate as a volunteer in the OSOAVIAKhIM work on jet propulsion and, for his part, promised to talk about it to Rynin and other colleagues. He also told me that the well-known author of popular science subjects, Ya.I.Perel'man, was also attracted by this project.

Over 30 years have passed since then, but these events were carved into 124 my memory. I remember that in the next few days (this was in the Spring of 1931, around the end of March) I visited Rynin, discussed the calculation of rocket flight by my own method and, among other things, told him that I had joined the OSOAVIAKhIM and would work as a volunteer on rockets at the Office of Aerial Technology.

Rynin replied that OSOAVIAKhIM had also talked to him about it and that he, Gazhala, and Perel'man intended to participate in this work.

We met at numerous occasions, either at Rynin's house or at my own, having long conversations, making various proposals, and drawing plans on the development of work with rockets and the prospects of interplanetary travel.

So it was that the initial group for jet propulsion study was organized at the Leningrad OSOAVIAKhIM. It consisted of Rynin, myself, Gazhala, and Perel'man.

Ye.Ye.Chertovskoy, vice chairman of OSOAVIAKhIM, was fantastically active in organizing the rocket group. He recruited V.A.Artem'yev, B.S.Petropavlovskiy, A.N.Shtern, and others for the initial work.

In November 1931, at the Army and Navy House, the first public meeting of the activists took place, and LENGIRD was organized. The entire original group was elected to the presidium.

N.A.Rynin, in his introductory speech, told of the objects and problems of LENGIRD; this was followed by my report on my work on high-altitude rockets, on the future aspects of using rockets for exploration of the stratosphere and subsequent investigation of interplanetary space.

At the end, the meeting elected the executive committee of LENGIRD, consisting of V.V.Razumov as chairman, Ya.I.Perel'man as vice chairman, N.A.Rynin, and M.V.Gazhala.

At the next meeting, toward the end of 1931, about 40 persons were present. At this meeting it was decided to form smaller units for work on the study of jet propulsion.

After my paper on the work I had done, the activists were asked to pick their unit. In all, five groups were set up: Research: M.V.Gazhala, director; Planning and Designing: V.V.Razumov, director; Propaganda: Ya.I.Perel'man, group leader; Laboratory: I.N.Samarin, group leader; Rocket Site: Ye.Ye.Chertovskoy, 25 group leader.

Some five or six of those present, including the leaders, joined each group.

LENGIRD had no permanent building for its technical work. Each activist worked at home. The seminars on current problems also took place in our own homes, often at my apartment.

More extended conferences were held in a room in the attic of the Leningrad House of Technology, which Chertovskoy obtained for us.

V.I.Shorin, Chairman of the Leningrad OSOAVIAKhIM, took an active part in the formation of LENGIRD and afterwards also assisted in our work. In particular, he raised funds to pay for workmen and materials to build and test rockets, and also arranged for assignments of LENGIRD members to Moscow to coordinate their work with that of the Moscow branch of GIRD.

We were then able to link up with the Institute of Wire Communications, in whose workshops, at the personal requests of Shorin, a large high-altitude rocket with an aluminum body was built. Activists did the work on an unpaid basis in their free time, which naturally had an adverse effect on the work and interfered with its successful performance.

Draftsmen and workmen were paid from the funds of the Leningrad OSOAVIAKhIM; however, these payments were inadequate [redacted] had to be supplemented from other sources. For example, to raise funds for building the large high-altitude rocket, at the request of V.I.Shorin, I was sent to Moscow to see M.N.Tukha-

chevskiy, Deputy Peoples' Commissioner of Defense of the USSR.

My trip was successful; we received 15,000 rubles to pay the workmen for building rockets in the workshops of the Leningrad Institute of Wire Communications.

The activists, as already mentioned, were all volunteers. I should like here to recall one of the enthusiasts of that time on rocket work. This was the activist and public servant, aviation mechanic S.Lotsmanov, who was always to be found at my home drawing rockets.

I must also mention the active work of Ye.Ye.Chertovskoy, Vice Chairman /26 of OSOAVIAKhIM, and P.F.Fedoseyenko who, like me, worked in the public interest as a volunteer.

Both of them devoted a good deal of work and effort to organization and operations of LENGIRD. For example, Ye.Ye.Chertovskoy, enthusiast and activist in rocket work, organized the first meetings, called for volunteers and found space for the meetings, while P.F.Fedoseyenko often visited the LENGIRD meetings and actively participated in their work.

Let me now tell you about the work done by the individual groups.

#### Research Group:

In December 1931, M.V.Gazhala organized seminars for the study of jet propulsion at LENGIRD. Lessons were given on higher mathematics, mechanics, and jet propulsion theory. The lectures were delivered by Gazhala and Samarin up to the end of May 1932. In October 1932, courses were organized for engineering and technical workers at the Leningrad House of Technology, at which lectures on jet propulsion theory were delivered by Gazhala, Petropavlovskiy, and Rynin.

In addition, in November 1932, courses on jet propulsion were organized at Leningrad for persons with elementary or advanced technical education. The lessons given were on higher mathematics, mechanics, thermodynamics, chemistry, jet propulsion theory, strength of materials, and materials science. The instructors were Gazhala, Samarin, Petropavlovskiy, and A.N.Shtern.

In September 1932, at the workshops of one of the Leningrad plants, small rockets of three different types with solid-propellant rocket engines were built: high-altitude rockets, rockets with panels, and ballistic rockets.

Tests were made at the proving grounds on the OSOAVIAKhIM terrain by the leader of the Research Group, M.V.Gazhala. The results of the tests were satisfactory. Twenty metal rockets were also designed and ordered at machine shops for various charges of solid motors for altitudes up to 1 km. Gazhala supervised execution of the order.

#### Planning and Design Group:

/27

In 1932, under the direction of Engineer V.V.Razumov, the following rockets

were designed: A powder rocket flare with a climbing range of 5.0 km, a photographic rocket with solid motor for an altitude of 10.0 km, and a recording rocket with solid motor for an altitude of 10.0 km.

In the same year, the design of a liquid-propellant rocket with a rotary engine was started. It operated on liquid oxygen and gasoline, and had a ceiling of 5.0 km.

In 1933, the group made calculations and sketches for high-altitude rockets with ramjet liquid engines for a climbing range of 60, 100, and 300 km.

Subgroups to develop rocket engines for solid and liquid propellants were organized in the Planning and Design Group. Let us now consider the work of these subgroups.

The solid rocket engine subgroup, from 1932 to 1935, developed plans for solid motors under the supervision of V.A.Artem'yev. The engines designed by him were used in all experimental rockets, and successfully passed the tests on the proving grounds at the OSOAVIAKhIM, under the supervision of Gazhala. In 1934, experimental rockets with these solid motors were launched at the Zmeykova Station of the Aerological Institute in the city of Slutsk. These rocket tests were reported in the newspaper "Na Strazhe" (organ of the Central and Moscow Councils of OSOAVIAKhIM) in its issue of October 28, 1934. The article "Experimental Rockets" gives brief characterizations of the small experimental rockets and photographs of the large experimental rocket designed by Engineer Razumov.

The development of plans in the liquid-propellant engine subgroup was under the supervision of Engineer A.N.Shtern, who proposed the design of a rotary engine, LRD-D-1, burning liquid oxygen and gasoline.

#### Propaganda Group:

From January to December 1932, Ya.I.Perel'man gave lectures and reports at the large Leningrad plants on the problems and plans for stratospheric exploration by rockets and on flights to other planets. His lecture "By Rocket to the Moon" was highly successful.

Ye.Ye.Chertovskoy and M.V.Gazhala also took active part in the propaganda /28 efforts at the Leningrad plants. They also organized groups on rocket-engine models.

#### Work of the Laboratory Group:

At the end of 1932, organization of a testing facility was commenced under the supervision of I.N.Samarin. These facilities comprised a laboratory and workshops. The work included preparation of a project containing all above-enumerated objects with sketches, descriptions, and cost estimates.

According to plan, the testing station was to check all units and equipment before installation on the rocket and to test the entire rocket, fully assembled,

before its delivery to the rocket site.

The testing station provided appropriate test stands in isolated hangars for testing and rating the thrust of engines using solid and liquid propellants. The tests, in the established order, were to be made from remote-control consoles, in special rooms of the laboratory and test station.

In addition, the testing station also provided individual stands for testing the piping in assembled form, along with the tanks, apparatus and equipment for launching, combustion cutoff and proper operation of the liquid-propellant engines.

The primary tasks of the laboratory were to check and recommend propellant compositions of suitable ballistic characteristics for rockets with solid-propellant engines and the components for rockets with liquid-propellant engines; to check and calibrate the research instruments, optical and photographic apparatus, gyroscopic devices, etc. to be installed on the rocket, and to check the onboard radio control and the ground-based radio indicators.

The laboratory was also to be equipped with all apparatus and instruments needed to do work relating to rockets with solid and liquid motors.

In first approximation, it was assumed that the labor-consuming production of parts of the rocket, such as casing, tanks, stabilizers with control surfaces, etc. would be taken over by the workshops of the Leningrad Machine Works.

For this reason, the workshops of the testing station were only to assemble the rockets and install the tanks, build and install the piping, safety valves, 129 etc. This work made it necessary to have assembly and installation shops, fitting shops and copper-working shops, which were equipped with the necessary assembly stands, scaffolding, work benches, desks, etc.

However, the plan was never carried out, owing to lack of funds.

#### Work of the Rocket-Site Group:

The mission of the Rocket-Site Group related primarily to all work on rocket launching, delivery of the rockets to the launch pad, and all safety measures, specifically shelter and observation bunkers. In addition, all of the launching equipment was under the jurisdiction of this group.

Ye.Ye.Chertovskoy was the soul of the organization of all tests. Under his guidance, a sketch of the rocket site for launching experimental rockets was prepared.

Such was, in brief, the work of the individual groups of LENGIRD.

Let us now discuss, in somewhat greater detail, the work of the Planning and Design Group.

## I. SOLID-PROPELLANT ROCKETS

### 1. Photographic Rocket Designed by Razumov for a Climbing Range of 10,000 m

The proposed photographic rocket (Fig.1) for an altitude of 10 km, was designed to photograph ground localities.

The rocket consisted of a detachable nose (1) carrying a camera, a body (2) to which stabilizers (4) with rudders (5) were mounted, and four rocket engines (3) installed in the forward section. Pyroxylin smokeless powder was scheduled as the propellant.

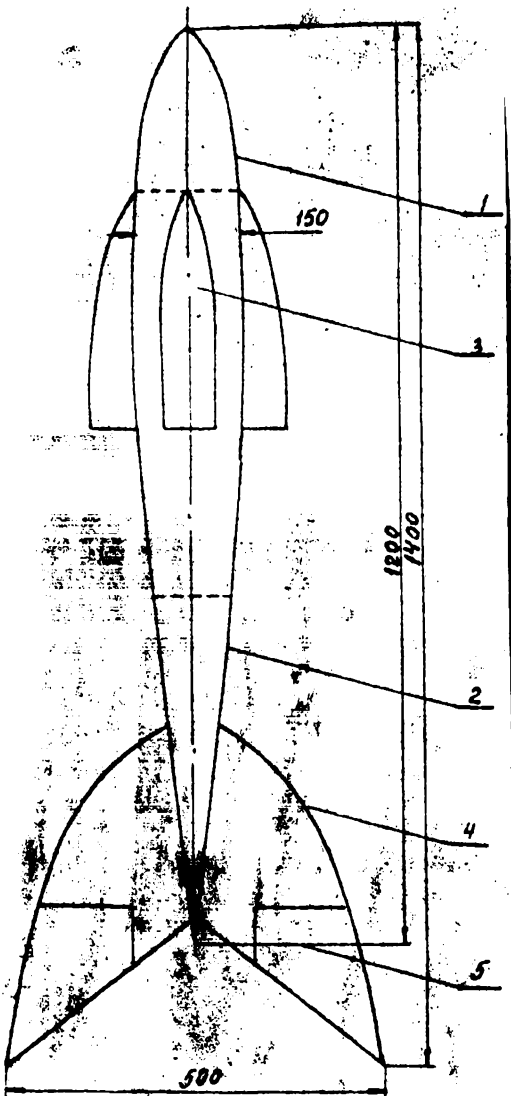


Fig.1

It was intended to obtain a photographic record of the rocket ascent, by measuring a base line on the ground which the rocket photographed from a specified altitude.

The camera was placed in the rocket nose, was ejected when the rocket reached its ceiling, and automatically took pictures during descent.

Smooth descent of the camera was /30 ensured by a parachute. The weight of the entire ejected camera was taken as not exceeding 5 kg.

It should be noted that also the body of the rocket was equipped with a parachute to provide smooth descent.

A draft of the project was prepared for the Leningrad branch of the Research Institute for Geodetics and Cartography. On January 23, 1932, the project was delivered to Comrade Buzayev. On February 14, 1932 a copy was sent to N.A.Rynin.

### 2. Rocket Flares Designed by Razumov. /31 for a Ceiling of 5.0 km; Tactical and Technical Requirements for Planning and Construction of a Prototype Experimental Rocket for a Ceiling of 5000 m\*

#### A. Purpose and object of rocket:

Possibility of supplementing or replacing searchlights, and also of dazzling

enemy pilots under antiaircraft fire\*.

B. Project-technical requirements for planning and building of rockets:

- 1) Portability of rocket manufacturing facilities.
- 2) Simple operation with the rocket not requiring specially trained personnel.
- 3) Rocket charge preparable at one of the chemical plants of Leningrad.
- 4) Manufacture of the rocket costing as little as possible and permitting mass production.
- 5) High initial rate of ascent.
- 6) Ceiling of 5000 m in vertical ascent from the liftoff point.
- 7) Possibility of obtaining illumination at any altitude within the limits of the ceiling (use of a variable-time fuze or sequential charges for various altitudes).
- 8) Impacting of rocket not to cause damage or start fires on the ground.
- 9) Launching sequence from the pad to ensure proper timing of firing order so as to provide continuous illumination if needed.
- 10) Launcher to be designed so as to permit launching from the ramp at an angle of  $45 - 90^{\circ}$  with all-around traverse of  $360^{\circ}$ .
- 11) Starter and rocket launcher to be of simplest design and to require no special launch sites.
- 12) All structural materials for the rocket to be produced in the USSR. /32
- 13) Rocket to illuminate specific air regions, if possible without illuminating the ground.

General Description of the Rocket (Fig.2)

The rocket consists of: a head (1) which houses an illuminating device, a parachute, and an ejector; four solid motors (2); an axial boom (4) to whose top the motors are mounted by retaining springs (3). The rear part of the boom is provided with four stabilizers (5) attached to the boom (4) over shafts (6); in the working position, the stabilizers are blocked by the stops (7).

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\* The tactical and technical requirements and the general description of the rocket discussed here are given in the same form in which they were prepared in 1932.

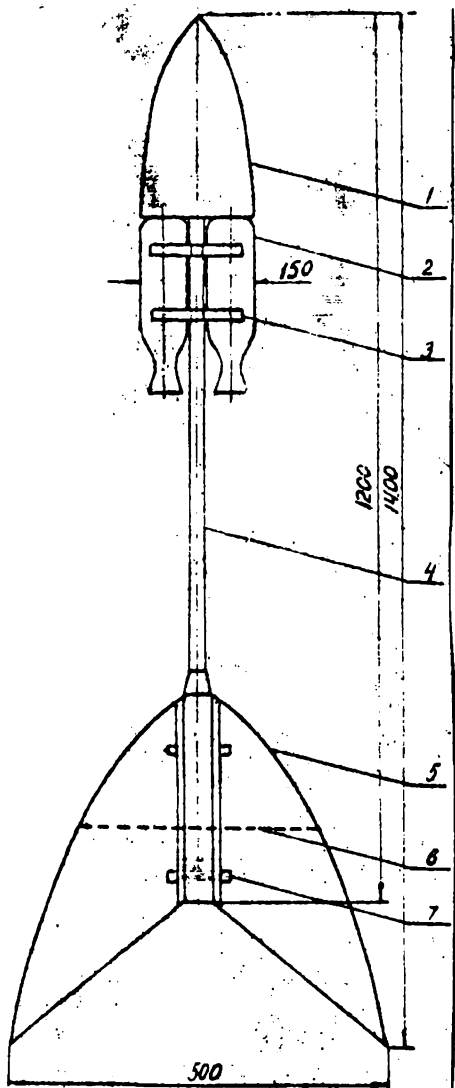


Fig. 2

When the rocket reaches the predetermined altitude, the head (1) is separated by the ejector. Together with the nose section, a parachute with the illuminating device is also ejected. In descending, the head spins with its ogive downward and the parachute is deployed above it; the illuminating device begins to operate and illuminates a given region of the air, while the head screens the light and prevents illumination of the earth's surface.

At the same time, the remainder of the rocket, consisting of the burned-out solid motors (2), the shaft-boom assembly (4), the ejector and stabilizers (5), begins to descend, turning with the motors (2) pointed toward the ground. Simultaneously with its rotation, <sup>133</sup> the rocket body, with the stops (7) released by the ejector, frees the stabilizers (5) whose surfaces, which now begin to rotate, function as propeller blades thus ensuring a slow descent of the rocket body to the ground.

The nose (head) section of the rocket is made of aluminum, the engine combustion chambers and nozzles of stainless steel, and the shaft-boom assembly of thin-walled steel tubing. The stabilizers are of aluminum.

The engines are individually dismountable. The number installed on a given rocket depends on the altitude required. They are placed alongside the rocket and manually forced into the spring clamps (3), without the use of tools or other devices.

The rocket propellant is smokeless pyrox-  
ylin powder with the following characteristics:

Density .....	1600 kg/m <sup>3</sup> ;
Volume of gaseous combustion products of 1 kg powder, at 0°C and 760 mm Hg, including water vapor .....	840 dm <sup>3</sup> ;
Combustion temperature .....	2460°C;
Ignition point .....	168 - 172°C

The preliminary design of the rocket flare was delivered on February 26, 1932 to N.A.Rynin for Comrade Kotov, Chief of Staff, Military Artillery Academy. On May 5, 1932, the draft was delivered to M.V.Gazhala for the construction of prototypes at the Leningrad Machine Works. Tests were performed under his control in September 1932 at the rocket site on the terrain of the Leningrad OSOAVIAKhIM and gave satisfactory results.

3. Recording Rocket Designed by Razumov for a  
Climbing Range of 10.0 km

The recording rocket with a ceiling of 10.0 km (Fig.3) was designed for procuring data on barometric pressure, temperature, and density of the atmosphere, at an altitude of 0 - 10 km above sea level. The required instrumentation was to be installed in the head of the rocket.

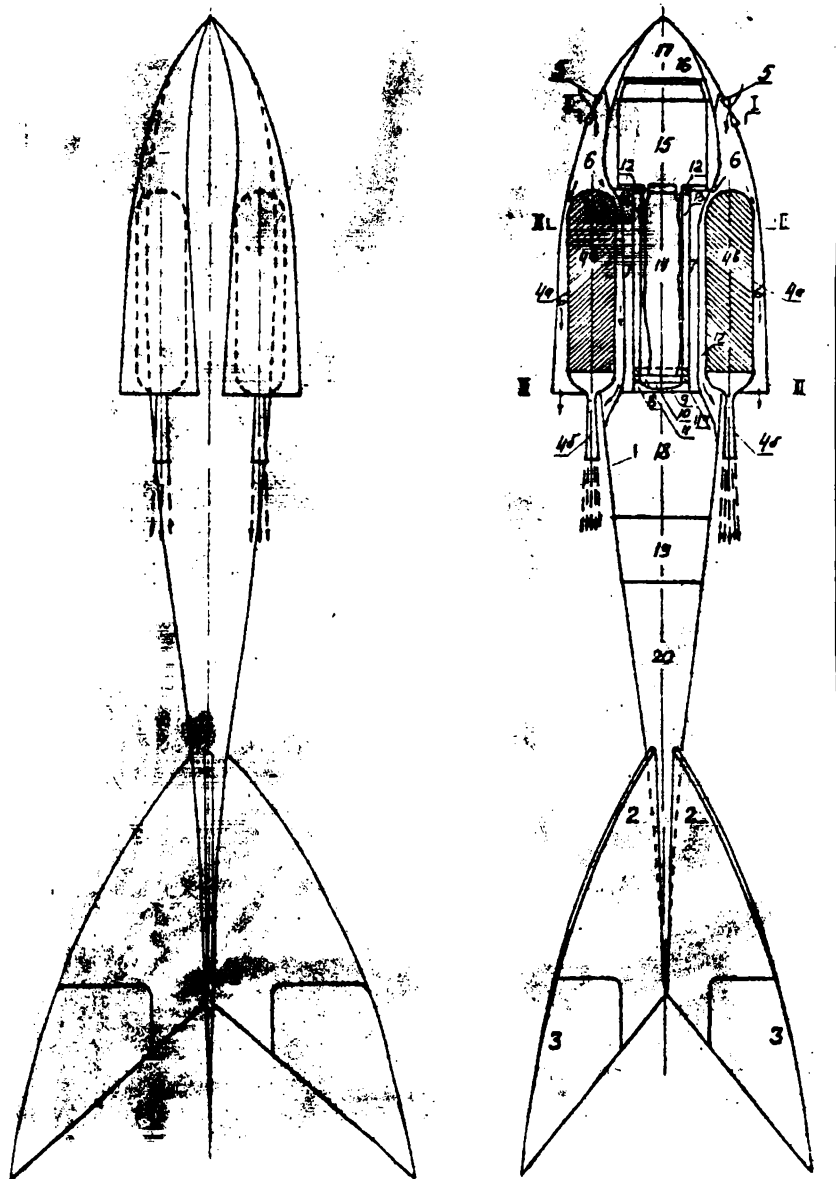


Fig.3

The plan provided that, on reaching maximum altitude, the nose section would automatically separate from the body of the rocket and the rocket head, with the recording instruments, would descend smoothly by parachute. The body, head, and

stabilizers were of aluminum. The rocket had four rocket engines housed in the front section. Smokeless pyroxylin powder was to be the propellant. /35

The solid motors were provided with steel combustion chambers with nozzles of heat-resistant steel. The outer combustion chamber was cooled by a current of air passing through annular passages in the rocket body.

The rocket comprised the following principal parts:

1) Case; 2) stabilizers; 4) rocket engines consisting of a) combustion chambers and b) nozzles.

A cooling system with the coolant passages (6) and the vents (5) was to be built in the body of the rocket. At the locations of the combustion chambers, the rocket body was provided with thermal insulation (7). The mechanism for separating the rocket head with the recording instruments and for ejecting the parachute consisted of the following parts: wooden base plate (8), cups for the ejecting charge (9), explosive charge (10), piston (11), two rubber sealing rings (12), and four struts of dural tubing (13), to keep the parachute (14) in the folded position.

The recording instruments were placed in the cylinder (15), to which the shroudlines of the parachute (14) were attached. To diminish the ejection shock on ejection of the cylinder with the recording instruments (15), a rubber shock absorber (16) was used, and, in addition, a buffer section (17) was placed in the rocket nose to soften the impact of the rocket head, together with the cylinder (15) and the recording instruments, at the instant of landing.

Figure 3 also shows: remainder of the body (18), containing a gyroscope section (19) for controlling the rudders (3), and, finally, the rear section of the rocket body (20) carrying the four stabilizers (2).

The preliminary design of the rocket was developed under orders of the LENGIRD Research Group for presentation to the Leningrad Geographic Institute. The rocket was subsequently simplified and, in smaller sizes, was built in the versions: high-altitude with plates and ballistic type, which were given the designation "M.V.Gazhala experimental rockets".

These rockets were tested on the rocket site on the OSOAVIAKhIM terrain, using V.A.Artem'yev solid motors. The altitude reached by these rockets was of the order of one kilometer.

## II. ROCKETS WITH LIQUID-PROPELLANT ENGINES

/36

### 1. Recording Rocket of Razumov Design with LRD-D-1 Engine of Shtern Design

Figure 4 is a drawing of the rocket with a rotary engine LRD-D-1 operating on liquid propellants.



The LRD-D-1 engine designed by A.N.Shtern, was a rotary rocket engine. The propellant was fed through pipes running along the arms on which the rocket engines were mounted. The engine nozzles were cut off obliquely so that the reactive force had a component in the horizontal plane controlling the lever perpendicularly. Both lever and engines were attached to the bearing of the vertical shaft. This formed a rotary system in which the propellant was fed to the engine under the action of centrifugal forces. Figure 5 gives a schematic sketch of the engine. It should be pointed out that the rotating masses not only supply fuel to the engine but also produce a gyroscopic effect ensuring stability in flight. The material of the engine was steel. The total weight of the rocket was 90 kg including the structural weight of 36.2 kg (body assembly, 20.2 kg; engine, 16 kg) while the weight of the propellant was only 25% of the overall weight of the rocket, or 38% without counting the weight of the payload.

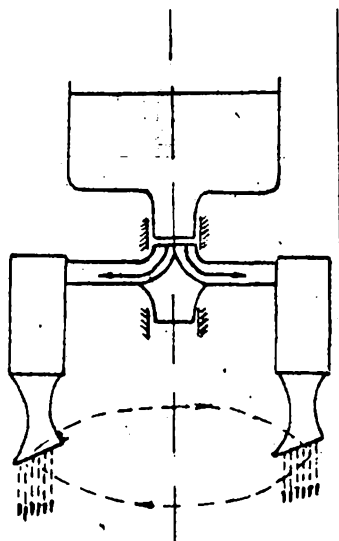


Fig.5

The thrust of the engine was 200 kg at an exhaust velocity of 2000 m/sec. The walls of the combustion chamber and the nozzles were cooled by liquid oxygen evaporated in cooling jackets.

The rocket was built at the shops of the Lenin-<sup>/38</sup> grad Wire Communications Institute in 1932.

The rocket, its drawing, and individual engine parts (combustion chamber and nozzle) were exhibited at the All-Union Conference on the Conquest of the Stratosphere from March 31 to April 6, 1934.

At that time, the LRD-D-1 engine had not yet been completely developed and its completion had been indefinitely postponed; therefore, it was decided to launch the rocket with a solid motor for preliminary aerodynamic check tests and observation of its behavior in flight. The rocket was finally launched at the end of 1934 with a solid-propellant engine designed by V.A.Artem'yev.

## 2. Rockets of Razumov Design with Liquid-Propellant Rocket Engines

Recording rockets of Razumov design with liquid-propellant rocket engines (altitude 60 and 300 km) went only as far as the first stage of preliminary design, completed on February 27 and November 25, 1933 respectively. The author drew the plans of these rockets for LENGIRD on his own initiative, in consultation with N.A.Rynin.

Both these rockets were designed to secure data on barometric pressure, temperature, and volumetric weight of the air of the upper layers of the stratosphere. Detailed data of the rockets are given in Table 1, and Fig.6 shows the approximate positions of the onboard devices and equipment, using the following numeration:

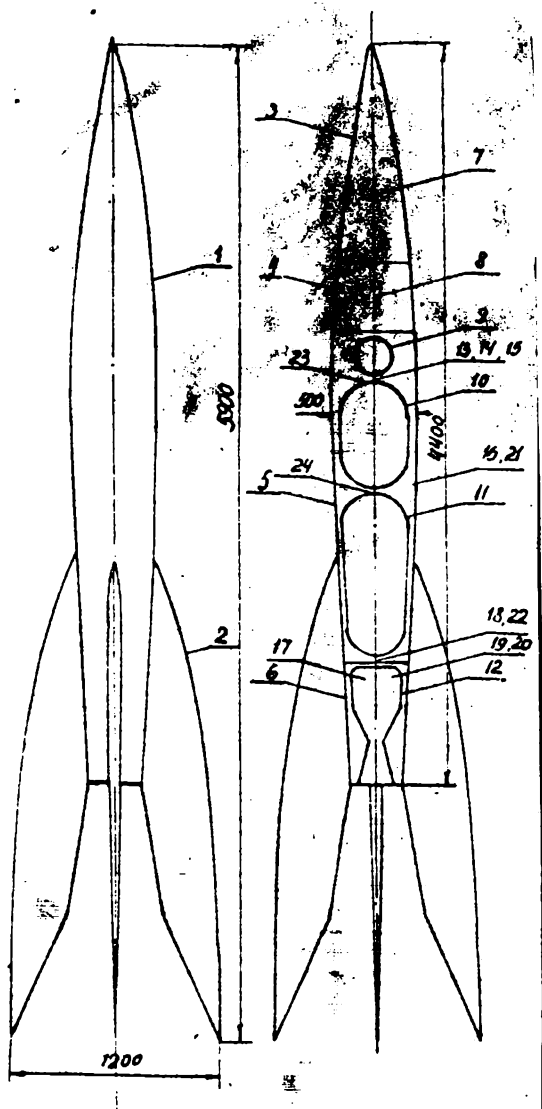


Fig. 6

1) Body; 2) stabilizers; 3) nose section; 4) compartment for recording instruments; 5) center section; 6) rear section; 7) parachute; 8) recording instruments; 9) compressed-air cylinder; 10) gasoline tank; 11) liquid oxygen tank; 12) engine; 13) reducing valve, 150/25 kg/cm<sup>2</sup>; 14) valve for launching 39 rocket; 15) compressed-air pipe through reducer (13) to gasoline and liquid oxygen tanks; 16) pipe to gasoline injectors; 17) gasoline injectors; 18) liquid oxygen pipe in cooling jacket of combustion chamber and nozzle; 19) collector; 20) oxygen injectors; 21) no-return valves in gasoline line; 22) no-return valves in liquid oxygen line; 23) safety valves in gasoline tanks; 24) safety valves in liquid oxygen tank.

The body (1) was to have been made of Kol'chug aluminum alloy (dural). Outside the body, in the rear, there were four stabilizers (2). The rocket was designed for vertical ascent and therefore had no rudder.

There were four compartments inside the body.

The first compartment (3) forming the rocket nose housed the parachute (7), designed for smooth descent of the entire rocket after reaching its maximum altitude.

The second compartment (4) was to contain the recording instruments (8).

The third compartment (5) forming the center section of the rocket contained: a spherical compressed-air tank (9) under a pressure of 150 kg/cm<sup>2</sup>, from where, through the reducing valve (13), compressed air under a pressure of 25 kg/cm<sup>2</sup> passed through the pipe (15) into the gasoline tank (10) and the liquid oxygen tank (11). 42

In the compressed air line, in front of the reducing valve, there was a valve (14) for launching the rocket.

The fourth compartment (6) (forming the rear section of the rocket) carried the engine (12), a ramjet engine operating on liquid propellant.

TABLE 1

## ROCKETS FROM THE PLANNING AND DESIGN GROUP OF LENGIRD

Name of Rocket	Date of Project Initiation	Dimensions		Diameter of Body	Weight		
		Overall Length of Rocket	Length of Body		Rocket with Fuel	Fuel	Payload
		Meters		Kilograms			
1	2	3	4	5	6	7	8
Razumov photo-survey rocket	Jan. 1932	1.35	1.2	0.25	26	6	5
Razumov illuminating rocket	Feb.18, 1932	1.2	0.5	0.15	18	3	2
Razumov recording rocket	Mar.23, 1932	2.11	1.79	0.23	30	10	5
Razumov recording rocket with Shtern IRD-D-1 engine	Nov.25, 1932	2.665	1.47	0.35	90	22.69	31.41
Razumov recording rocket with liquid rocket engine	Feb.27, 1933	3.62	2.45	0.35	95	43.7	11.0
Razumov recording rocket with liquid rocket engine	Nov.15, 1933	5.9	4.4	0.50	150	110	10.0
LENGIRD experimental rockets	1934	0.5	-	0.05	0.5	-	-
Razumov recording rocket	1934	2.665	1.47	0.35	90	22.69	31.41

(cont'd)

TABLE 1 (cont'd)

Engine	Fuel, or Fuel Components	Reactive Thrust on Liftoff, kg	Calculated Exhaust Ve- locity of Gases m/sec	Maximum Velocity of Rocket, m/sec	Maximum Altitude of Rocket, km	Duration of Rocket Flight	
						With Operating Engine, sec	After Engine Burnout, sec
9	10	11	12	13	14	15	16
Four solid motors	Smokeless pyroxylin powder	270	1860	446.5	10.0	4.33	50
Four solid motors	Smokeless pyroxylin powder	81	1860	348	5.0	4.35	40
Four solid motors	Smokeless pyroxylin powder	148	1860	744	10.0	12.7	63
Rotary engine	Gasoline, 4.89 kg; liquid oxygen 17.8 kg	200	2000	-	5.0	-	-
Ramjet engine	Gasoline, 12.5 kg, liquid oxygen 31.2 kg	1000	2000	958.4	60.0	28	98
Ramjet engine	Gasoline 30 kg; liquid oxygen 80 kg	1571	2000	2170	300	51	222
Ramjet engine	Powder grain	-	-	-	-	-	-
Ramjet engine	Powder grain	-	-	-	-	-	-

The engine consisted of a combustion chamber and a nozzle, both cooled by liquid oxygen evaporated in cooling jackets. Fuel was supplied to the combustion chamber by compressed air with the aid of a system comprising: compressed air tank (9), pipelines (14), (15), and (16) with their fittings, pressure reducing valve (13), valves, ignition device, and injectors, in short the entire equipment required for starting, stopping, and correctly operating the engine.

Unfortunately these rockets were not further developed, owing to unforeseen circumstances.

\* \* \*

To summarize some of the results of LENGIRD's work, let us recall that the beginning of the 1930's saw the organization, in Leningrad, of a Center where enthusiasts of rocketry and interplanetary travel assembled. It must be borne in mind that the staff working at LENGIRD on the creation of rockets included many members of widely differing levels of education, with different specialties and different occupations.

LENGIRD did valuable work in making rocketry popular, thus helping to establish cadres of volunteer specialists on rocket engineering. The Center worked in close contact with the Moscow GIRD. Exchange of reports was practiced, and directions of future work were outlined. In exchange of practical experience, the Moscow GIRD was given the draft of one of the LENGIRD rockets and an original calculation of its flight (allowing for gravity and resistance of the ambient medium), performed on the basis of my method.

In conclusion, I might state that LENGIRD's work was of indisputable significance in the development of the idea of rocket engineering in the USSR, the creation of new rocket designs, and the popularization of scientific and technical thinking on the conquest of space.

IN THE SOVIET NATIONAL ASSOCIATION OF HISTORIANS OF  
NATURAL SCIENCE AND TECHNOLOGY

The Aviation Section of the Soviet National Association of Historians of Natural Science and Technology continued its work in 1962 - 1964. The Section today has about 200 members, including mostly everybody who is working in the field of the history of aviation science and engineering in the USSR. The largest groups are working in Moscow (82 members), Leningrad (65 members), and Kiev (31 members). The Section also has aviation historians from Tbilisi, Riga, Kharkov, Saratov, Tartu and other cities. During the period just past, the activity of the Section was in the following main directions:

- a) investigation of various questions of the history of aviation science and engineering;
- b) preparation of a collective work: "Fifty Years of Aviation Science and Engineering in the USSR" (Aviatsionnaya nauka i tekhnika v SSSR za 50 let);
- c) preparation of a history of the leading design offices of the USSR aircraft industry;
- d) compilation of a handbook of biography and bibliography of USSR workers in aviation science and engineering.

Below, we give an outline of the work of the principal groups of the Section.

Moscow

From September 1962 to June 1964\*, nineteen sessions of the Section were held, at which the following papers and communications were presented:

Anoshchenko, N.D.: The First Balloon Flight Specifically for Scientific Observations, Arranged by the St. Petersburg Academy of Sciences on June 30, 1804 (On the 160th Anniversary of the Flight of Academician Ya.D.Zakharov [O pervom polete aerostata spetsial'no dlya nauchnykh nablyudeni, organizovannom Peterburgskoy Akademiyey nauk 30 iyunya 1804 g. (K 160-letiyu poleta akademika Ya.D.Zakharova)]).

Anoshchenko, N.D.: Organization and Work of the "Flying Laboratory" (On the 45th Anniversary of its Establishment) [Organizatsiya i rabota "Letuchey laboratorii" (K 45-letiyu so dnya osnovaniya)].

Anoshchenko, N.D.: Pre-History of Soviet Gliding (Predystoriya sovetskogo planerizma).

Bazurin, R.G.: Brief Historical Survey of the Main Trends of Space Study

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\* Reports of the Sessions held up to Summer of 1962 were published in Tr. Inst. Istorii Yestestvozn. i Tekhn. Akad. Nauk SSSR, No.38, Moscow (1961), pp.321-324; No.45, Moscow (1962), p.256.

- (Kratkiy istoricheskiy obzor osnovnykh napravleniy kosmicheskikh issledovaniy).
- Belolipetskiy, V.I.: Pages from the History of the Mechanics of Space Flight (Iz istorii mekhaniki kosmicheskogo poleta).
- Bondaryuk, M.M.: Application of the Theory of Academician B.S.Stechkin to the Design of Ramjet Engines (Prilozheniye teorii akademika B.S.Stechkina k sozdaniyu pryamotochnykh vozdushno-reaktivnykh dvigateley).
- Bubnov, I.N.: Main Stages of Development of the Space-Rocket Boosters of the United States. Analysis of the Degree of Success of Launchings of American Artificial Earth Satellites and Space Vehicles (Osnovnyye etapy razvitiya kosmicheskikh raketnositeley SShA. Analiz rezul'tativnosti zapuskov amerikanskikh iskusstvennykh sputnikov Zemli i kosmicheskikh letatel'nykh apparatov).
- Znamenskiy, G.A. and Merkulova, N.M.: On the 60<sup>th</sup> Anniversary of the Wright Brothers' Flight (K 60-letiyu poleta brat'yev Rayt).
- Kaznevskiy, V.P.: The 25<sup>th</sup> Anniversary of the Launching of the World's First Rocket with a Ramjet Engine (25 let so dnya zapuska pervoy v mire rakety s PVRD).
- Kozlov, S.G.: A Long-Term Plan of Publication of Papers on the History of Aviation and Rocket Engineering by the Institute (O perspektivnom plane publikatsii rabot po istorii aviatsionnoy i raketnoy tekhniki v izdaniyakh Instituta).
- Kozlov, S.G.: Working up Questions of the History of Aviation in the Union Republics and the Large Industrial Centers of the USSR (O razrabotke voprosov istorii aviatsii v soyuznykh respublikakh i krupnykh promyshlennykh tsentrakh strany).
- Matyuk, N.Z.: The Activities of N.N.Polikarpov's Design Office (Deyatel'nost' konstruktorskogo byuro N.N.Polikarpova).
- Merkulov, I.A.: On the 25<sup>th</sup> Anniversary of the Launching of the USSR's First Two-Stage Ramjet-Powered Rocket (K 25-letiyu so dnya zapuska pervoy v SSSR dvukhstupenchatoy rakety s vozdushno-reaktivnym dvigatelem).
- Merkulov, I.A.: On the First Flights of Rocket Aircraft in the USSR (O pervykh v SSSR poletakh na raketoplanakh).
- Merkulov, I.A.: The 30<sup>th</sup> Anniversary of the First Experimental Flight Studies on the GIRD Ramjet Engines (30 let so vremeni pervykh letnykh eksperimental'nykh issledovaniy pryamotochnykh vozdushno-reaktivnykh dvigateley GIRD-a).
- Mosolov, I.Ye.: Lenin and Aviation (Some Documents and Other Materials) [V.I.Lenin i aviatsiya (nekotoryye dokumenty i materialy)].
- Moshkin, Ye.K.: Scientific Papers and Engineering Developments by F.A.Tsander in the Field of Rocket Engineering (Nauchnyye trudy i inzhenernyye razrabotki F.A.Tsandera v oblasti raketnoy tekhniki).
- Okromeshko, N.V.: The First Soviet Aircraft Engine, M II (On the 35<sup>th</sup> Anniversary of its Realization) [Pervyy sovetskiy aviatsionnyy motor M II (35 let so dnya sozdaniya)]. /45
- Pobedonostsev, Yu.A.: 35 Years since Formulation of the Theory of the Ramjet Engine by Academician B.S.Stechkin (35 let so vremeni sozdaniya akademikom B.S.Stechkinym teorii vozdushno-reaktivnykh dvigateley).
- Putilov, K.A.: Scientific and Experimental Preparation for the Flight Tests of the Ramjet Engine on Aircraft Designed by N.N.Polikarpov and by A.S.Yakovlev in 1939-1944 (Nauchno-eksperimental'naya podgotovka letnykh ispytaniy PVRD na samoletakh konstruktsii N.N.Polikarpova i A.S.Yakovleva)

v 1939-1944 gg).

- Razumov, V.V.: Pages from the History of the Leningrad Jet-Propulsion Study Group (LENGIRD) [Iz istorii Leningradskoy gruppy izucheniya reaktivnogo dvizheniya (LENGIRD)].
- Ruzhitskiy, Ye.I.: Present Helicopter Building and the Prospects for its Development (Sovremennoye vertoletostroyeniye i perspektivy yego razvitiya).
- Skvortsov, G.V.: The Development of Rocket Engines in the United States during World War II (Razvitiye raketnykh dvigateley v SShA v gody vtoroy mirovoy voyny).
- Skvortsov, G.V.: The Development of Liquid-Propellant Rocket Engines in the United States in 1945-1953 (Razvitiye zhidkostnykh raketnykh dvigateley SShA v 1945-1953 gg.).
- Shavrov, V.B.: On the 40<sup>th</sup> Anniversary of the Realization of the First All-Metal Aircraft in the USSR (K 40-letiyu sozdaniya pervogo tsel'nometallicheskogo samoleta v SSSR).
- Shavrov, V.B.: On the 75<sup>th</sup> Anniversary of the Birth of the Aircraft Designer K.A.Kalinin (K 75-letiyu so dnya rozhdeniya aviakonstruktora K.A. Kalinina).
- Shavrov, V.B.: The State of Russian Aircraft Construction before the October Revolution and in the First Years of Soviet Power (Sostoyaniye otechestvennogo samoletostroyeniya pered Velikoy Oktyabr'skoy sotsialisticheskoy revolyutsiyey i v pervyye gody Sovetskoy vlasti).

In addition, the Section, together with the Sector of the History of USSR Technology of the Institute of History of Natural Science and Technology, USSR Academy of Science, held a joint discussion of the prospectus of the Division of "Aviation Science and Engineering" for the publication of sketches of the history of technology in the USSR in a large number of volumes. The prospectus of the division was prepared by a group of authors headed by Academician A.N. Tupolev. During its discussion by members of the Section, a number of critical remarks and requests, directed toward improvement of the composition of the Division, were made.

The preparation of the handbook "Biobibliogr. Dictionary of USSR Workers in Aviation Science and Technology" (Biobibliografich. slovar' otechestvennykh deyateley aviatsionnoy nauki i tekhniki) was continued. The work on the volumes: "Aircraft Construction" (compiled by V.B.Shavrov), "Aircraft Engines" (compiled by N.V.Okromeshko and M.P.Pal'nikov), "Helicopters" (compiled by A.M. Izakson) and "Aeronautics" (compiled by A.I.Dumchev) has now been completed. The remaining volumes are also scheduled for submission in the next few months.

The Section has recently commenced compilation of a large collective work "Fifty Years of USSR Aviation Science and Engineering" (Aviatsionnaya nauka i tekhnika v SSSR za 50 let) which is to be completed by the 50<sup>th</sup> Anniversary of the Revolution. Most of the group of authors have been selected, the Editorial Board has been approved, and will be headed by Professor I.F. Obraztsov, Rector of Moscow Aviation Institute imeni Ordzhonikidze, and Doctor of Technical Sciences. /46

## Leningrad

The Leningrad group of the Section now has 65 members, including 7 professors and 14 Candidates in Sciences. The work of the group is directed by an executive committee composed of P.P.Kvade, I.Ya.Shatoba, F.G.Popov, A.I.Dumchev, I.I.Smaga, A.A.Goleyskiy, V.L.Korvin, V.S.Mitin, and I.F.Fanechkin.

From January 1963 to April 1964\*, a total of twelve sessions were held at Leningrad.

On January 30, 1963, F.G.Popov presented a paper on the activity of Prof. K.P.Boklevskiy, Dean of the Faculty of Naval Architecture, St.Petersburg Polytechnic Institute, in the training of aviation cadres. The author emphasized the great work done by Boklevskiy in organizing theoretical aviation courses at the Faculty of Naval Architecture in 1911, and also noted his role in training aviators in the theoretical disciplines, in the selection of professors and instructors, in the organization of the aerodynamics laboratory, etc.

On March 15, S.N.Podkaminer presented a paper on the subject: "Forty Years of the Civil Air Fleet". The paper evoked wide interest, since it touched on questions of the development of the Civil Air Fleet not only on the historical plane but also on the level of its prospects. He dwelt particularly on the design features of the aircraft of the future, on the striving to attain absolute flight safety and profitability.

On May 23, members of the Section attended a Session of the Academic Council of the Leningrad Branch of IIVeIT (Institute for the History of Natural Science and Technology), and heard a paper by Prof. Kornel'skiy of the Henri Gerlach University on the subject "Study of the History of Science in the United States". This paper gave a general idea of the method of studying the history of science in the United States and its principal trends.

On September 30, I.Ya.Shatoba presented a paper on the subject "The Jet Aircraft of F.G.Geshvend". The author stated that the life of Geshvend was now completely traced and that much of what had been previously unknown was now accurately defined. It was also established that Geshvend began to deal with questions of the design of rocket aeronautic vehicles under the influence of I.I.Treteskiy, who was a friend of his. Furthermore, the author noted the historical significance of Geshvend's work, since his project contained interesting innovations. /47

On October 30, K.F.Kosourov presented a paper on the subject "Naval Aviation, a Historical Review, Design Features, and Prospects of Development". This paper related to the history of science. It gave a detailed characterization of hydroplanes from the very beginning of naval aviation, indicating the design

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\* Reports of the work done by the Leningrad group before 1963 have been published in Tr. Inst. Istorii Yestestvozn. i Tekhn. Akad. Nauk SSSR, No.45, Moscow (1962), pp.257-258, and in the collected papers: Questions of the History of Natural Science and Technology (Voprosy istorii yestestvoznaniya i tekhniki), No.17, Moscow (1964), pp.262-263.

characteristics of the most widely used types of aircraft. He dwelt in particular on the development of Soviet naval aviation and specifically on the designs by D.P.Grigorovich. In conclusion, the author discussed the prospects of development of naval aviation in the USSR and abroad.

On November 30, a Joint Session of the Section and the Leningrad Aero Club was held in the House of Defense of DOSAAF, on the occasion of the 55th anniversary of the foundation of the All-Russian Aero Club and the 40th anniversary of the beginning of Soviet glider sport. I.Ya.Shatoba, a member of our Section, presented a paper on the role of the All-Russian and Leningrad Aero Clubs in the development of aviation and gliding in this country. This anniversary session was attended by about 350 aviators of all generations, from those who began their work in aviation in 1908 - 1909 down to the present time. The session was highly successful.

On December 25, Yu.A.Val'kova presented a paper on the subject "V.P.Vetchinkin, Outstanding Soviet Aerodynamicist". He told of Vetchinkin's work in aerodynamics, emphasized that he also had done work on stress analysis of aircraft and had written a number of papers on air navigation, astronomy, ballistics, jet flight, etc., which are among the most precious treasures of our aviation science.

On January 9, 1964, L.L.Kerber presented a paper on the subject "The 75th Birthday of Academician A.N.Tupolev". This long paper gave a detailed description of Tupolev's career, beginning with his first steps in the field of aviation down to the present. Kerber discussed the path traveled by the designer Tupolev from his first aircraft ANT-1 to the most recent jet liners, known far beyond the borders of the USSR. He emphasized the great organizational talent of Tupolev, his profound theoretical knowledge, and his bold conceptions in designing each new aircraft. /48

In conclusion, the speaker warmly lauded the personal characteristics of Andrei Nikolayevich Tupolev as a chief designer, a man, and a colleague.

On February 5, P.P.Kvade presented a paper "The 60th Birthday of Aviator Chkalov". It discussed in detail his life, emphasizing his striving, as a young man, to obtain an appointment to the Civil Air Fleet, his great aptitude for flying, and his perseverance in the work of an aviator. He noted Chkalov's energy, his work as a test pilot, where his flying skill and his knowledge as a test pilot manifested themselves in a particularly impressive manner.

After the paper, a coworker of Chkalov, V.Zarkhi, a retired mechanic, presented his recollections.

On February 26, two papers were presented:

A.I.Dumchev "30 Years since the Flight of the Stratosphere Balloon 'OSO-AVIAKhIM-1' to an altitude of 22,000 meters".

I.Ya.Shatoba "The Rocket-Powered Balloon of I.I.Tretesskiy".

On April 1, B.G.Broude gave a talk on the designer S.V.Il'yushin (in honor

of his 70<sup>th</sup> birthday).

The Leningrad group of the Section has the following plans for the near future:

Expand the mutual exchange of work experience, by news items and papers on topics of current interest.

Continue popularization of the work of the Section in Leningrad, actively enlist in its work all persons working in the related research organizations.

Enlarge and deepen debates on books in aeronautics, aviation, and astronautics.

Actively promote further work on the collection of data for a handbook on the history of aviation in St.Petersburg-Leningrad, publication of which is scheduled for the Fiftieth Anniversary of the Revolution.

### Kiev

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The Kiev group of the Section was organized in February 1962. It now has 31 members. The work of the group is directed by a committee composed of: M.A.Kochegura (Chairman), I.S.Laponogov (Vice Chairman), Ye.V.Koroleva (Academic Secretary), M.B.Lyakhovetskiy and N.S.Shelukhin (Members of the Committee).

In two years in Kiev, a total of 16 sessions of the Section were held, at which a large number of papers and communications were presented. A detailed report of the Kiev group will be published in one of our next issues.

Translated for the National Aeronautics and Space Administration by the O.W.Leibiger Research Laboratories, Inc.

HISTORY OF AVIATION AND COSMONAUTICS, VOL. II

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USSR Academy of Sciences. Soviet National Association of  
Historians of Natural Science and Technology, Moscow, 1964.

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\*NASA editorial note: Only a summary of this Russian article is presented here due to the fact that histories on the development of rocket boosters are available in English.

HISTORY OF AVIATION AND COSMONAUTICS, VOL. II  
Brief History on the Development of Rocket Boosters in the USA

I. N. Bubnov

[Summary of Pages 3-55]

A brief summary of the development of space launch vehicles in the USA is presented. The early history of very large ballistic rockets in the USA, such as the V-2 and the Viking, is presented, followed by a description of the development of rockets in the USA, such as the Atlas and Titan I. A detailed description of these rockets is given, including such characteristics as fuel weight, length, maximum frame diameter, fuel, operational time of the engine, maximum velocity, etc.

The expansion of the USA space program is then discussed, with a description of the functions of NASA within the framework of this program. In 1960 the United States developed a special space vehicle called "Scout" for use in the launching of satellites. A light rocket was needed to launch small satellites weighing up to 100 kg. A detailed table presents basic data on the US space vehicles used at the present time, including "Thor-Agena A", "Thor-Delta", "Atlas Agena", "Scout", "Titan 2", "Saturn I", etc.

It is stated that one general feature of the development of US space launch vehicles is that a single form is used successively on different vehicles. Thus, the construction of the V-2 rocket was subsequently modified and used on the rockets "Viking", "Jupiter", "Thor", "Atlas" and, finally, "Saturn I". The stages of the first "Vanguard" launch vehicle were subsequently used on the rockets "Atlas-Able", "Thor-Delta", etc.

One great achievement of American rocket construction is the successful use of liquid hydrogen as the fuel in the upper stages. Three successful tests ("Atlas-Centaur" and "Saturn I") point to the future use of hydrogen as a fuel.

The launch vehicle having the greatest reliability (91.5% as of January 1, 1964) is "Thor-Delta". "Thor-Agena" has a reliability of 77.5%, and "Atlas-Agena" -- 77.1%.

Only recently have the American efforts been concentrated in certain basic directions, and there has been a tendency towards unification. This has led to excellent results (success of the "Saturn" program). It is emphasized that the development of US launch vehicles has been based for a long period of time on medium- and long-range ballistic rockets. To a significant extent, this has retarded the progress of space research in the USA due to the low load capacity and low reliability of ballistic rockets. At the same time, the low load capacity of space vehicles has stimulated the production of small and relatively light satellites.

Prehistory of Soviet Gliding\*

N. D. Anoshchenko

The Soviet Union recently noted the 40th anniversary of Soviet gliding.

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\* A report given on December 2, 1963 at the 57th meeting of the Aviation Section of the Soviet National Society of Historians of Natural Science and Technology.

\*\* Numbers in the margin indicate pagination in the original foreign text.

Gliding began with the First All-Union Gliding Tests in the Crimea conducted in 1923 by the Society of Friends of the Air Fleet of the Soviet Union (ODVF SSR). Therefore, we would like to pay our respects to the memory of the Russian scientists and inventors who in the past have by their labors blazed trails in the development of gliding and modern aviation. We should remember that the first heavier-than-air flying machine in which man was able to tear himself from the earth and fly was a glider.

N. A. Arendt (1833-1893), a doctor of medicine, in his article "A Contribution to the Problem of Aerial Navigation. On Gliding Flight", published in the journal *Znaniye* in 1873, was the first in Russia to propose a motorless apparatus with fixed wings for gliding and soaring flight, using for this purpose only the energy of the oncoming stream of air. Arendt supported his views with numerous experiments in launching paper models of gliders and frozen birds of different species, and in 1888 he published in Simferopol' his work "On Aerial Navigation Based on the Principle of Soaring by Birds. On Gliding Flight." It should be noted that Arendt also was the first to advance the idea of establishing a surface trainer for preliminary instruction in flights on gliders.

Since the material, published in the collection of documents in the archives "Aeronautics and Aviation in Russia Before 1907", presents a sufficiently comprehensive description of Arendt's work, we consider it superfluous to repeat this. Let us merely indicate that this material corroborates the assertion that Arendt /57 is one of the founders of Russian gliding and of the science of soaring flight.

The creator of the first airplane with a steam engine, A. F. Mozhayskiy, as early as 1876 constructed and personally tested in flight large aerial kites which he launched on a rope. This compels the author to consider A. F. Mozhayskiy the first man in Russian to go up in towed gliders.

A great role in the birth of modern aviation was played by Otto Lilienthal, who in 1891-1896 constructed several monoplane and biplane catapult gliders. In them, Lilienthal made about two thousand gliding flights from a hill and launching tower which he built especially in Lichtenfeld. These flights of Lilienthal's and his book The Flight of Birds as the Basis of Flying, which was translated into many languages, including Russian, played a substantial role in popularizing aviation and gliding ideas.

"The Father of Russian Aviation," Professor N. Ye. Zhukovskiy, whom we may now with complete justification consider also the "Father of Russian Gliding," was deeply interested in Lilienthal's experiments, and in 1895 during a journey abroad was present at his flights.

As is known, Zhukovskiy as early as 1877 began to conduct preliminary experiments on the study of bird flight and a series of experiments to determine the basic laws of aerodynamics. In 1891, as though in response to the reproach by Arendt that scientists were quite unable to give a mathematical foundation for bird flight, he made his noted report "On the Soaring of Birds," in which he made a profound study of, and provided a theoretically correct explanation for, the principle underlying the soaring flight of birds and predicted the possibility of performing the loop and other figures of aerobatics in gliders and future airplanes.

When visiting Lilienthal, Zhukovskiy for the first time saw a man in the air flying on artificial immobile wings, i.e., in a glider, and thus giving a practical demonstration that the creation of lighter-than-air flying machines was completely possible and that his, Zhukovskiy's, theoretical computations were not at variance with practice.

Even after the tragic death of Lilienthal, when in practically all countries glider flights were at a standstill, Zhukovskiy, speaking on August 25, 1898 at the Tenth Congress of Natural Scientists and Physicians in Kiev, said, "I think that the manner of investigating the problem of aeronautics by means of a soaring flying machine (i.e., a glider--the author) is one of the most reliable. It is simpler to add a motor to a well-studied gliding flying machine than to enter a machine which has never flown with a man."\* /58

Believing that the building of gliders and that flights in them were the needed school for future aviators and designers of heavier-than-air flying machines, Zhukovskiy organized in Moscow the "Circle of Gliding Experimenters," in the work of which Zhukovskiy's comrade -- the scientist and aviator, S. S. Nezhdanovskiy -- also took a most active part. Nezhdanovskiy was the first to give a theoretical and practical demonstration in his glider models that longitudinal stability in a flying machine requires an immobile stabilizer plane and that increase in transverse stability requires a certain "V" wing. This was his essential contribution in developing the design of future airplanes and gliders.

In 1908-1909, Zhukovskiy initiated the foundation of the first student gliding clubs in Russia ("Aeronautics Club of Moscow Technical University" and the similar club in the Moscow State University). The members of these clubs included such major scientists and designers as the Academicians A. N. Tupolev, and B. N. Yur'yev, Professors V. G. Vetchinkin, K. A. Ushakov, G. Kh. Sabinin, and V. A. Slesarev, and many other figures in aviation science and engineering.

Similar clubs were also organized in other cities (in Kiev -- the club of Professor N. B. Delone in the Polytechnical Institute, from which came such designers as D. P. Grigorovich, I. I. Sikorskiy, A. A. Fal'ts-Feyn, and others; in St. Petersburg the club of N. A. Rynin in the Institute of Communications Engineers, etc.), the members of which also played a major role in the development of domestic aviation in our country and of its science and engineering.

In completing this brief survey of the pre-revolutionary period, we must still speak of the first glider and soaring pilot in Russia, since a distinctive feature of Soviet gliding is his mastery of precisely those soaring flights about which Arendt and Zhukovskiy wrote.

In 1911 a report appeared in the press that the Wright Brothers had again returned to gliding in order to create a device capable of performing soaring flights, and that during the last experiments in the Kitty Hawk, Orville Wright had succeeded in remaining on their motorless machine for 9 min., 45 sec. /59

In the following year, our amateur glider pilot, S. P. Dobrovol'skiy, decided

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\* N. Ye. Zhukovskiy. *Sobraniye sochineniy* (Collected Works), Vol. VII, Moscow-Leningrad, p. 26, 1950.

to repeat their experiments in his village of Agaymany, Taurida (Tavricheskaya Guberniya), and in a strong autumn wind, he was the first in Russia to make a series of successful soaring flights over the steppe, lasting at times more than five minutes.

Deprived of its needed support, however, gliding in Russia had gone into a decline by the beginning of the First World War. Only the Great October Revolution, which unchained the creative forces of the nation, created all of the prerequisites for the development of gliding among us.

The most important factor in the prehistory of Soviet gliding is in our opinion the organization of the special "Aero-Workshop Gliding Class" in the "Flight Laboratory" -- that first scientific research institution of the Air Force, created by Soviet power in 1918.

In 1919 the reorganization of the "Flight Laboratory" occurred, founded by the aviator B. I. Rossinskiy, and the Scientific Board under the chairmanship of N. Ye. Zhukovskiy, in which the author was appointed a Board member, became its head. In the spring of 1919, he developed a plan for creating an "Aero-Workshop" with a gliding class designed to "study the elements involved in a theory of constructing motorless aeroplanes (i.e., gliders) and flights on them" in the "Flight Laboratory."\*

The project was supported by N. Ye. Zhukovskiy, B. I. Rossinskiy, V. P. Vetchinkin, and other members of the Board, and on May 25, 1919, by Decree No. 16 of the "Flight Laboratory", the creation of an "Aero-Workshop" and of a special "Gliding Class" was announced. This was the beginning of the development of modern Soviet gliding and the historic link connecting the past of Russian gliding to the present day of Soviet soarers.

On September 7, 1919, in an empty room of the summer restaurant "Mavritaniya" in Petrovskiy Park, the "Gliding Class" was opened at which N. Ye. Zhukovskiy -- that founder of gliding in our country -- gave a lecture on the history of gliding; therefore, we consider this date to be the beginning of history of Soviet gliding.

Forty students were enrolled in the "Gliding Class" from the candidates /60 for the aviation schools in the Main Air Force, the workers in aviation factories, the Moscow School of Military Pilots, and the "Vseobuch" (public schools), but subsequently this number had to be increased, since the influx of those wishing to study gliding was extraordinarily large.

The students studied the history of aviation and gliding, the basic elements in designing gliders for strength, aerodynamics, meteorology, and other disciplines. Lectures were given by V. P. Vetchinkin, V. S. Denisov, S. S. Gromov, myself, and other specialists, and the curricula of the courses and lectures were examined and approved by the Scientific Board of the "Flight Laboratory" under the chairmanship of N. Ye. Zhukovskiy.

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\* Nauchnyy arkhiv muzeya N. Ye. Zhukovskogo (Science Archives of the N. Ye. Zhukovskiy museum), Nos., 371, 368/I-368-5.

Studies went along very successfully, and the students were already preparing to start the independent construction of a glider which they had designed, but then the wooden building of the "Aero-Workshop" was demolished for wood, since that year Moscow was without fuel. It is understandable that without rooms for studying and designing gliders the "Aero-Workshop" had to cease its activity.

Despite its short existence, the "Aero-Workshop" was not only the first Soviet nucleus of gliding in our country but also gave the first impetus to the subsequent development in the USSR of mass gliding, whose successes are now rightfully the pride of our people.

The group of former students of the "Gliding Class", from among the flying and engineering personnel of the Moscow School (A. V. Nadashkevich, V. P. Nevdachin, and others), had already in the next year of 1920 decided to continue the work which had been begun and attempted to found a "glider pilots' club" in the Aviation School.\* This attempt was not crowned with success, however, since the civil war and devastation forbade sufficiently serious occupation with this matter.

Continuing to popularize ideas of gliding through the journal Vestnik Vozdushnogo Flota (Air Force Herald) (see Nos. 8-9 and 10-11 for 1921), we, relying on experience abroad, again proved that if the USSR needed a powerful Air Force for which hundreds of skilled flying and engineering personnel would be required, it was now necessary to devote serious attention to an immediate and extensive reactivation of gliding. For this purpose it was requisite that such authorized organizations as the Zhukovskiy Central Aero-Hydrodynamic Institute (TsAGI) and the Main Air Force (Glavvozdukhoflot) should urgently deal with this problem.

At that time we advanced the idea of conducting All-Union Gliding Contests /61 and of founding a special "gliding center."

It was probably under the influence of this agitation that V. S. Pyshnov (then a young student, but now an Honored Worker in Science and Engineering), with the help of his comrades, constructed a glider in the Moscow Aviation Technical School -- the Institute of Engineers of the Red Air Force in the same year of 1921. In this glider, Pyshnov, B. I. Cheranovskiy (the future designer of gliders and airplanes of the "flying wing" type), V. V. Utkin-Yegorov, and other members of the group of glider enthusiasts which had been organized in November, 1921, made about twenty catapult and free "hoists" and glides in Annenhof Square. Then the glider was broken up, and not put together again.\*\*

At approximately the same time another group of aviation workers (from among the former students of the "Gliding Class") came to me with the request to help them officially organize a "Glider Enthusiasts" Club in the Aviation School

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\* See the letter of K. K. Artseulov. Nauchnyy arkhiv muzeya. N. Ye. Zhukovskogo, No. 107/6.

\*\* See letter of V. S. Pyshnov. Nauchnyy arkhiv muzeya. N. Ye. Zhukovskogo, No. 2210/8.

and to provide the necessary material base for it. The authorities of the Main Air Force decided to found such a glider enthusiasts' club, not in the School of Military Pilots, but for the Scientific Editorial Board of the Air Force. And so on November 10, 1921, the Scientific Board held a meeting of workers and a number of invited individuals (among whom were V. P. Vetchinkin, V. S. Pyshnov, A. V. Nadashkevich, K. K. Artseulov, V. P. Nevdchin, S. S. Gromov and others), at which I gave a report "On the Need for Organizing a Club of Glider Enthusiasts to Popularize the Idea and to Develop Scientific Technical Matters Pertaining to Soaring in the Air."

Our proposal was accepted and on the recommendation of V. P. Vetchinkin, who at that time was fascinated with the study of bird soaring, it was decided to call this club "Soaring Flight". To organize it, the 'triumvirate' of N. D. Anoshchenko, I. A. Valentey, and Yaroshevskiy was chosen.\*

The former pilot A. A. Zhabrov was chosen as the first chairman of the glider enthusiasts club "Soaring Flight," and Vs. Garshin was chosen as the secretary.

Thus, in November, 1921 the first Soviet club of glider enthusiasts was /62 born and formed, which was subsequently fated to play a significant role in the mastery in the USSR of the art of making soaring flights and in the popularization of Soviet gliding.

For the normal development of Soviet gliding, however, a reliable material base was still requisite which only the scientific and technical organizations of the Air Force could afford.

It may therefore be considered that the development of Soviet gliding was put on solid footing only at the end of 1922, when the gliding enthusiasts began to receive statutory material support from the controlling organs of the Red Air Force, who saw in it a powerful reserve from which could subsequently be drawn skilled reinforcements for the personnel it needed.

The little-known history of this crucial moment in the development of mass Soviet gliding is in short as follows:

In the autumn of 1922, Comrade A. A. Znamenskiy, Chief Commandant of the Air Force of the Republic, read in No. 117 of the foreign newspaper Nakanune (On The Eve) an article about the Rhön contests of German glider enthusiasts and about their remarkable achievements in making soaring flights. Not believing what he had read, he sent the article to the Chairman of the Scientific-Technical Committee of the Main Air Force, Comrade P. S. Dubenskiy, with the inquiry of whether the printed material were true, to which Dubenskiy on September 4, 1922 wrote back:

"There are apparently no exaggerations in the article. N. D. Anoshchenko, whom I have entrusted with making an exhaustive report on this question in the Scientific-Technical Committee, is specially occupied with this subject."

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\* Nauchnyy arkhiv muzeya, N. Ye. Zhukovskogo, No. 2213/4.

"Last year N. D. Anoshchenko attempted to organize gliding but was unable to do anything because of lack of means.

"At present the question of gliders is evoking great interest."\*

On the same day, I received from Dubenskiy, with the notation "Urgent", the suggestion, "On next Friday to report to the Scientific Technical Committee 'on the state of gliding amongst us and abroad and on the immediate problems and prospects of its development,'" which I did on September 15, 1922, after which the Scientific-Technical Committee passed the following resolution:

"To acknowledge that gliding is deserving of every support on the part of the organs of the Air Force; to designate credits from the funds for experimental construction for the purpose of building the most interesting glider designs; to involve TsAGI, the Scientific-Technical Committee, and other scientific organizations of the Air Force, making it incumbent upon one of the members of the Committee to follow the development of gliding and periodically to report to the Scientific-Technical Committee about it. To create favorable conditions for conducting experiments with gliders."\*\*

/63

Only after this resolution of the Scientific-Technical Committee of the Main Air Force, which was a historic resolution in the fate of our gliding, and in the adoption of which such competent scientist members of the Scientific-Technical Committee as A. N. Tupolev, B. S. Stechkin, N. R. Brilling, N. V. Fomin and others actively participated, did Soviet gliding receive the necessary scientific, material, technical, and legal base for its development.

Thus the work for the restoration of gliding in the USSR which we had begun with the support of N. Ye. Zhukovskiy, as early as 1919, in the "Gliding Class of the Aero-Workshop" was completely acknowledged and supported by the highest scientific center of the Red Air Force -- its Scientific-Technical Committee.

With the founding in 1923 of the Society of Friends of the Air Force (ODVF), with its Sports Section and "Center of Motorless Aviation", clubs of gliding enthusiasts, eager for practical work spontaneously began to appear everywhere. Therefore, it is quite natural that the All-Union Conference of the ODVF held in June, 1923, set before the authorities the problem of uniting the 40-50 spontaneously founded gliding enthusiasts' clubs and of organizing an All-Union Contest for glider pilots."

Thus gradually Soviet gliding was born, and the long expected day for reviewing its achievements was approaching. In view of the lack of experienced glider pilots and of gliders which had already been proven, it was decided to conduct not a contest, but only "Representative Experimental Tests of Soviet Gliders" and to establish a rigorous preliminary check of the strength and reliability of the machine construction, of the skill of their pilots, and of the safety of launches. Under the chairmanship of the TsAGI representative, V. P. Vetchinkin, the composition of the technical Committee was approved, including a representative of Main Air Force inspection.

\* Nauchnyy arkhiv muzeya, N. Ye. Zhukovskogo, No. 2213/1.

\*\* Nauchnyy arkhiv muzeya, N. Ye. Zhukovskogo, No. 2213/3.

On August 27, 1923 the ODFV SSSR approved the matter and set up an "Organizing Committee for Arranging the First All-Union Representative Experimental Tests of Motorless Flying Machines in 1923" composed of the chairman of the "Center of Motorless Aviation," K. K. Artseulov; the deputy chairman of the Sports Section and representative of the Main Air Force, N. D. Anoshchenko; /64 a representative from the Zhukovskiy Air Force Academy, V. Ya. Arrison; a representative of TsAGI, V. P. Vetchinkin; and military pilots, Engineer I. N. Vinogradova, A. Ye. Rayevskiy, and others.

And thus it was that 40 years ago, from November 1 to 18, 1923 in the Crimea in the Koktebel' Region on Mt. Uzun-Syrt were held the First All-Union Gliding Tests at the end of which pilot L. A. Yungmeister brilliantly executed the first soaring flights in the USSR. His achievements surpassed foreign records, which permitted V. P. Vetchinkin to write "Russian gliders, constructed in complete independence, without any copying from foreign models, are in no way inferior in their flying qualities to the best foreign soaring planes, while Russian pilots in three weeks achieved the same results as were achieved in Germany only in the third year of gliding contests."\*

Such is the brief history of the formation of Soviet gliding which, based on documentary evidence, permits us to state that our gliding, whose cradle was watched over by N. Ye. Zhukovskiy, owes its formation in the USSR and its initial development to participation of such scientific organizations as the "Flight Laboratory" with its scientific Board, and its "Aero-Workshop Gliding Class," the Scientific Technical Committee of the Main Air Force, the Air Force Academy, the TsAGI, etc., under the direction of the Party and the Soviet Government.

Therefore, the beginning of the reactivation of gliding in the USSR must be assigned not to 1923, but to 1919, which also emphasizes the significance given to gliding by the Party and Soviet Power even in those difficult days of universal devastation and civil war.

Finally, in this short sketch, the author also wanted to show in clear outline that historic "relay race of generations" which created the continuity of the ideas underlying the development of gliding in our country -- from Arendt and Zhukovskiy to Tupolev, Yur'yev, Rossinskiy, Vetchinkin, and the author of this article; from them to V. S. Pyshnov, A. S. Yakovlev, S. V. Il'yushin, O. K. Antonov, B. I. Cheranovskiy, and so on to our days, when the new contingent is continuing to aid the development of our aviation science and engineering, utilizing for this purpose the gliding activity whose prehistory and formation in the USSR we have related in the present article.

#### Works on the History of Aviation and Cosmonautics in the Ukraine

M. A. Kochegura

The section on the History of Aviation and Cosmonautics of the Ukrainian /65 Division was organized in February, 1962, when the initiating group of the Aviation Community of the city of Kiev -- aviation veterans and enthusiasts of

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\* Pervyye opyty pareniya v SSSR (First Soaring Experiments in the USSR). Moscow, p. 87, 1924.

aviation history -- gathered in their first session, choosing the Organizational Committee comprised of eight people. From the first days of the activity of the Organizational Committee, its sessions, along with organizational matters, heard and discussed reports and communications on the history of aviation in the Ukraine. The members of the Organizational Committee took an active part in the organization and conducted a festive meeting dedicated to the 75th anniversary of the birth of the founder of aerobatics -- the military pilot P. N. Nesterov -- and discussed and reviewed the scenario of the moving picture Mërtraya petlya (Looping the Loop).

The first organizational meeting of the members of the Section took place on April 16, 1962. At this meeting general problems and the work of the Section were discussed, and a Board consisting of five people was chosen. The main problem of the Section in the coming years is to collect materials for compiling and publishing, by the 50th anniversary of the Great October Socialist Revolution, a work on the history of aviation in the Ukraine in the form of essays or a monograph. In addition to the history of aviation, this book should contain sections on the history of aeronautics and of rocket engineering.

The Section also set itself the task of uniting historians of aviation living in the Ukraine and of collecting materials on the history of aviation in the possession of veterans and other individuals. By the end of 1962 this Section counted more than 30 members, including about 10 from other cities of the Ukrainian SSR - Khar'kov, Odessa, Vinnitsa, L'vov, Lutsk, and Sevastopol'. The membership of the society has at present become stabilized at approximately the same number. Some of them have left and some have been duly accepted. The new entries participate in the meetings of the Section members.

Meetings of the members of this Section are proceeding very actively. The /66 main question in almost every meeting is the production of a book on the history of aviation. The publication of such a book has been approved and supported by the First Secretary of the Central Committee of the Communist Party of the Ukraine, Comrade P. Ye. Shelest, and the Chairman of the State Committee on Coordination of Scientific Research Work in the Ukrainian SSR, A. N. Shcharban', Member of the Academy of Sciences UkSSR. At present, the prospectus of the book on aviation history in the Ukraine has been sent for examination to the Gostekhizdat (State Publishing House for Technical Material), of the Ukrainian SSR. Reports on the work of the individual Section members on portions of the book on aviation history in the Ukraine are regularly heard at sessions of the Board and meetings of the Section members.

At sessions of the Board and general meetings of the members of the Section, in accord with the plan made for each half year, reports, communications, and reminiscences of aviation veterans, remarkable data on the history of aviation science and technology, and so on are presented and discussed. Before the presentation of any report to the Section, a short résumé of it is set forth by the reporter at a session of the Board, no later than a week before the Section meeting. After discussion of the contents of the report, the Board usually recommends that certain of its sections be developed and that the uninteresting elements be curtailed. Thus the Board can actively influence the quality of the report, while its author has enough time to ponder the remarks, proposals, and recommendations expressed in the Board.

Among the reports and communications heard at sessions of the Board and of the Section, are the following:

Zamlinskiy, V. A. (Lutsk) -- New Data on the Biography of One of the Pioneers of Cosmonautics, Yu. V. Kondratyuk.

Koroleva, Ye. V. -- The First Military Flights of Russian Pilots (On the 50th Anniversary of the Balkan-Turkish War).

Kochegura, M. A. -- The Works of Yu. V. Kondratyuk.

Laponogov, I. S. -- The Location of the Syrets Airport, Above Which P. N. Nesterov Looped the Loop.

Lyakhovetskiy, M. B. -- The Twentieth Anniversary of the Day of the First Jet Airplane Flight in the USSR.

Lyakhovetskiy, M. B. -- Flights to the North Pole.

Lyakhovetskiy, M. B. -- First Flights Across the North Pole to the USA.

Lyakhovetskiy, M. B. -- The Fortieth Anniversary of Main Air Force (GVF).

Lyakhovetskiy, M. B. -- The Pilot E. Kruten.

Ivashchenko, V. I. -- N. Kibal'chich and His Relatives Who Have Lived and Are Living in the Ukraine and in Other Republics of the Soviet Union.

Bondarenko, S. S. -- The First Repair Bases and Plants for Maintaining Air-planes in the City of Kiev. /67

Kochegura, M. A. -- V. A. Zamlinskiy's Manuscript "The Astronaut from Lutsk."

Sobolev, S. A. (Vinnitsa) -- On His Manuscript "A. F. Mozhayskiy in the Ukraine."

Suleymanov, M. Z. -- Fifteen Years' Operation of the AN-2 Airplane.

Kochegura, M. A. -- The Fiftieth Anniversary of the First Airplane Russkiy Vityaz' (Russian Hero).

Karatsuba, S. I. -- On the Work of the Gliding Club of Kiev Polytechnic Institute in the Twenties.

Koroleva, Ye. V. -- Fiftieth Anniversary of P. N. Nesterov's Loop.

Lyakhovetskiy, M. B. -- The Fortieth Anniversary of the Society of Aviation and Aeronautics of the Ukraine and the Crimea (OAVUK).

Rudnitskiy, Ya. R. -- The Celebration of the Fortieth Anniversary of Gliding in Kiev.

In addition, questions of memorializing the memory of the glider pilot, G. S. Tereverko and of the military pilot P. N. Nesterov were discussed. In response to a petition by the Section, the name of G. S. Tereverko was given to a street in the city of Tbilisi. Kiev architects are developing a project for the memorial to P. N. Nesterov which will be erected in the city of Kiev at the intersection of Brest-Litovsk Highway and P. N. Nesterov Street.

The Section also heard a report on communication with foreign libraries on questions of the history of aviation and on sessions of the Aviation Section of the Soviet National Society of Historians of Natural Science and Technology (Moscow) which were attended by members of our Sections. At one of the meetings of the Section part of Ye. V. Koroleva's manuscript "Biographical Study of the Pilot M. Yefimov" was discussed.

Since the day the Section was organized, the following works by its members have been published on the history of aviation in the Ukraine:

Lyakhovetskiy, M. B. -- Talanovytyy Ukrayins'kyy umilets', Narysy istoriyi npyrodoznavstva i tekhniky (A Talented Ukrainian Specialist. Sketches of the History of Natural Science and Technology). Number 3, Vydavnytstvo Akademiya nauk, UkrSSR, 1963.

Lyakhovetskiy, M. B. -- V ognе srazheniy. 40 let Grazhdanskogo vozdushnogo flota. Sbornik statey. (In the Fire of Battle. Forty Years of the Civil Air Fleet, a Collection of Articles). Redizdat Aeroflota, 1963.

Lyakhovetskiy, M. B. -- Nadezhnyye kryl'ya respubliki (The Republic's Trustworthy Wings). Izdatel'stvo "Znaniye". Kiev, 1962.

Zamlins'kiy, V. O. -- Vin npokladav shlyakh u vsesvit (Pro odnogo z pioneryv radyans'koy astronavtiki. Yu. V. Kondratyuk (He Blazed the Trail to the Universe. One of the Pioneers of Soviet Astronautics, Yu. V. Kondratyuk). Vydavnytstvo "Znaniya," Kiev, 1963.

Zamlins'kiy, V. O. -- Avstronavt (The Astronaut). Vydavnytstvo "Kamenyar," L'vov, 1964. /68

Moreover, in various newspapers and periodicals about 70 articles were published.

The following works on the history of aviation were prepared and sent to press:

Koroleva, Ye. V. -- They Were the First to Stride to Heaven (The First Russian Aviators).

Koroleva, Ye. V. -- A Sketch of New Documents from the Biography of the Pilot M. Efimov.

Kochegura, M. A. -- The Long-Standing Falsification of the History of Aerial Navigation.

Kārasuba, S. I. -- The Work of the Gliding Club of the Kiev Polytechnic Institute.

The following are being prepared for press:

Kovan', M. O. (Khar'kov). The Pilot Lavrent'yev (Second Edition of the book).

Tunitskiy, N. N. (Odessa). Naval Aviation.

Briling, G. G. (Vinnitsa). The Aircraft Designer Cheranovskiy, a Native of Vinnitsa.

Zamlinskiy, V. A. (Lutsk). The Kiev Engineer, F. R. Geshvend.

Chairman of the Bureau - M. A. Kochegura.

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## RUSSIAN HISTORY OF AVIATION AND ASTRONAUTICS VOLUME 3

N. D. Anoshchenko et al.  
Editors

## FROM THE EDITORS

This publication concerns the development of the theory of ramjet engines /3\* and the first aircraft with engines operating on the basis of this theory.

The date of the creation of the theory of air-breathing jet engines is usually considered 1929, the year in which Academician B. S. Stechkin's classic work appeared. This work served as the theoretical foundation in the development of all types of air-breathing engines, including ramjets.

Shortly after Stechkin's work was published, GIRD (Group for the Study of Jet Engines) in 1932 began engineering history's first experimental investigations of air-breathing jet engines, both on test stands and in flight, for which an experimental ramjet engine was installed in the body of an artillery shell.

The GIRD work continued with the development and flight-testing of rockets with air-breathing jet engines and ramjet-powered aircraft in which the engines were installed as auxiliary motors in aircraft designed by N. N. Polikarpov and A. S. Yakovlev.

An article in this collection is dedicated to each of these stages of the first period of work in the field of ramjet propulsion. Each article sets forth the basic facts and chief technical characteristics of the engines' construction.

The question of the present and future use of ramjet engines plays an important role in the evaluation of the significance of the ramjet theory. Therefore, along with the material on the history of ramjets, this collection contains two articles on the state-of-the-art and future development of the engine. The first theme is discussed in the article by Professor M. M. Bondaryuk, in which he gives a clear picture of the transformation of Stechkin's theory into actual modern ramjet-propelled aircraft. In his own article, Academician Stechkin has given a scientific prognosis of the future development of ramjets and their use in various craft.

The materials are reports presented 5 March 1964 at the joint meeting of /4 the Aviation and Space History section of the Soviet National Union of Historians of Natural Science and Technology of the USSR Academy of Sciences, All-Union Committee on Astronautics of the USSR DOSAAF (All-Union Cooperative Society for the Assistance of the Army, Air Force and Navy) and the M. V. Frunze Central House of Aviation and Astronautics. The article by Academician Stechkin was published in the journal "Aviation and Astronautics (Aviatsiya i Kosmonavtika)", No. 1, 1965.

\*

Numbers in the margin indicate original pagination in the foreign text.

As was stated above, the collection contains materials on only the first years in the history of ramjets. It does not include material on the later development of the theory of ramjets in the works of Soviet and foreign scientists, nor the wide experimental studies which have served as a basis for the modern development of ramjets. During the time preceding the publishing of the theory of air-breathing jets, as is witnessed by the extensive world literature, there were detailed experimental studies of ramjets and their components. Special attention was devoted to the study of the process of fuel consumption and the processes in the combustion chamber, studies of air-intakes for supersonic ramjets, and the development of ramjet control methods and systems. The structural tests preceding the development of high-efficiency ramjet engines have an exceptional importance. All these questions are to be clarified in later editions of the collection.

# RAMJET ENGINES FOR SPACECRAFT

B. Stechkin

~~N~~68 - 13567

The ramjet has a definite area of application. It is presently felt that the ramjet can be expediently used for flight at Mach numbers within the limits  $1.5 \leq M \leq 7$ , and there is reason to believe that the upper limit can be substantially increased (to  $M \approx 10-12$ ). At  $M \leq 1.5$ , the thermal efficiency in the ramjet cycle is quite low, as a result of which its specific thrust and fuel economy are too low to permit efficient practical use. At high velocities ( $M > 12$ ) the intake diffuser operates ineffectively and due to kinetic energy losses by the air, the combustion chamber temperatures becomes critically high. Progress hinges on our success in carrying out combustion at a high speed of air motion, so that the air entering the craft will be at least partially braked. There are also great hopes of using the ramjet with a liquid hydrogen propellant.

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The use of the ramjet at space-flight speeds ( $M \geq 28$ ) at altitudes of 90-100 km, as is necessary for oxygen buildup, for example, is still impossible. Future progress in the development of the ramjet can be foreseen due to the transfer to external (outside the craft) combustion accomplished at air speeds as high as desired.

Thus, the use of ramjets for spacecraft can presently be seen for rocket launching within a continuous atmosphere to speeds from  $M = 7-10$ . Launching may be effected either on a particular craft circling the Earth or directly on the rocket itself, in the first stage. Supplying air for the afterburning of rocket engine gases in rocket flight increases thrust, but this will not hold with the ramjet.

We will find a substantially wider field of application for the ramjet in the area of high-speed aircraft and in rockets not to be used in space flight.

35 YEARS AFTER THE CREATION OF THE THEORY OF AIR-  
BREATHING JET ENGINES BY ACADEMICIAN  
B. S. STECHKIN

Yu. A. Pobedonostsev

The rapid development of modern aviation, especially in its most recent period, is characterized primarily by the wide application of jet engines in aircraft. As a result of the transfer from piston to jet engines, aircraft flight speeds have multiplied. Jet engines have permitted manned flight in the atmosphere exceeding the speed of sound. /6

Of various types of jet engines, the air-breathing jet engine has attained the greatest application in present-day aviation.

As early as the middle of the last century, in 1867, Staff Captain N. A. Teleshov invented an engine which he named the "thermal air-blower" and which embodied the basic elements of the modern ramjet. Diagrams of similar engines abroad appeared substantially later, only in the first decade of the Twentieth Century.

In 1909, the Russian engineer N. V. Gerasimov evolved a design for a jet engine in which he planned to use a gas turbine as an air-compressor drive. It is noteworthy that the first models of this apparatus were built in our country by P. D. Kuz'minskiy in 1892-1897 and by V. V. Karavodin in 1908. The combustion chamber in the Karavodin turbine was in essence the first resonance-pulse jet.

In 1911, the engineer A. Gorokhov proposed a plan for an engine-compressor air-breathing jet engine. In this engine he proposed preliminary compression of the air in front of the combustion chamber in a compressor driven by a turbine engine.

The plan for an aircraft piston engine with turbine drive was first proposed in 1914 by the Naval Officer M. N. Nikol'skiy. The turbine was to have been turned by gases flowing from a liquid-propellant rocket engine.

The idea of a ramjet engine was first advanced (1907-1913) by the French engineer Rene Laurent. However, its first theoretical development, structural design as well as the tests with ramjet engines were accomplished much later by our Soviet specialists.

Much effort was directed toward the theoretical and engineering tests of this apparatus, as well as its application to a large number of aircraft, with the aim of aiding their takeoff from the Earth's surface. This was accomplished by one of the pioneers of interplanetary travel and rocket technology--Fridrikh Arturovich Tsander.

The first references to jet engines are in his 1922 dictations, which have been collected. In his investigations, Tsander gave great importance to the use of the terrestrial atmosphere to facilitate launching heavily loaded

spacecraft. He strove to eliminate the necessity of carrying an oxidizing agent on the rocket in the dense atmospheric layers of the Earth's surface. However, fuel consumption is quite high at the beginning of the spacecraft's motion, during launch. Its flight speed is quite low with respect to the speed of gas exhaust from the rocket nozzles. Therefore, the dynamic efficiency of rocket is insignificantly low, while at the same time the initial launch weight is at its highest. Consequently, it is precisely at the beginning of the spacecraft's motion that the greatest expenditure of heavy fuel occurs.

Freedom from the need to supply the jet engine with a heavy oxidizing agent on the first part of its flight promises great possibilities for lightening the launch weight of the craft. If atmospheric oxygen is used during takeoff, the reduction in the craft's weight and dimensions will be substantial. Tsander understood this very well much earlier than others. He carried out in-depth theoretical investigations on the thermodynamic cycle of such engines and arrived at an interesting new conclusion that the relatively low efficiency of jet engines at low flight speeds might be significantly increased through great overexpansion of combustion products leaving the engine exhaust nozzle at supersonic speeds and their subsequent compression simultaneous with cooling to pressures of the surrounding medium which the final products of combustion enter. Tsander called /8 this specialized setup a "reverse cone." However, in those days to those in gasdynamics it was still unclear how such compression could be effected without great energy losses from the gas flowing at supersonic speed. All tests to attain such compression with low losses had poor results. Only in the 1940s did the first practical studies in this direction yield good results. Only very recently were actual structural diffusers created which yielded compression with high efficiency in the supersonic gas flow.

In 1923, the Soviet engineer V. I. Bazarov perfected his design of a gas-turbine engine with a centrifugal compressor. The Bazarov design incorporated all of the basic features of modern gas-turbine engines. In his engine, atmospheric air reached the centrifugal compressor through an intake duct. From the compressor it progressed to the combustion chamber, where it was divided into two flows, one of which was used for fuel burning, while the second was admixed to the combustion products to lower their temperature before they reached the turbine blades. Passing through the turbine, the gases flowed out through the nozzle at high speeds. The power of the turbine in the Bazarov engine exceeded the required compressor power. Its excess was used for turning the air propeller. Thus, the full engine thrust consisted of the thrust of the propeller with the reactive force of the gases flowing from the nozzle.

In 1924, B. N. Yur'yev developed a design for a reaction propeller. The hub of this propeller had a central opening through which air entered. To obtain high economy, the air was initially compressed by the centrifugal compressor rotated by the propeller itself. Passing through the intake opening, the air hit the tubular blades of the propeller. Moving around the blades, the air was additionally compressed by centrifugal force. At the end of the blades, fuel ignited at high temperatures was injected into the compressed air.

The combustion products flowed out into the atmosphere from the nozzle placed at the end of the blades and created a reactive force which turned the propeller.

Each year the work of Soviet innovators broadened. Foremost scientists, designers and inventors worked diligently to give our aviation new, light and small but powerful engines capable of giving it further impetus toward attaining greater and greater speeds. This creative work of the Soviet specialists allowed us to define the basic contours of future jet engines. But there was a lack of a fundamental general theory--the bases for future design operations and in-depth theoretical investigations in this region. /9

For a correct, efficient realization of the bold plans of our designers, the theoretical basic plans of our designers the theoretical bases for designing the various jet engines themselves had to be evolved.

In response to this urgent need on the part of the designers and the requirements for developing our aviation, Soviet science also succeeded in solving this fundamental challenge.

In 1928, one of the closest successors of N. Ye. Zhukovskiy, today Academician Boris Sergeyevich Stechkin, was lecturing on hydrodynamics at the Mechanics Department of Moscow's Bauman Higher Technical Institute. "One day, in December of 1928," recalls one of the former students of that period Stepan Aleksandrovich Aksyutin, "Stechkin turned to the students and offered to tell them 'something new and interesting'."

As you might imagine, the students, who along with Aksyutin included Anan'yev, Kamenomostskiy, Knyazev, Krichevskiy, Lavochkin, Sokolov, Tayts, and others, readily agreed. He then began to set forth a new theory he had developed on rocket engines. With all the rigor of classical gasdynamics he set up equations for the thrust and efficiency of engines operating in an expandable medium in the most general case.

For a noncompressible fluid without considering heat the question of the force of the reaction of the jet, a fluid, passing through a jet engine was comprehensively developed earlier by N. Ye. Zhukovskiy and set forth in his classical works "Reactions of Inflowing and Outflowing Fluids" and "The Theory of Vessels Set into Motion by the Force of a Water Jet."

Similar investigations were first performed by B. S. Stechkin for the flow of an elastic medium.

He analyzed in detail the question of supplying energy to an airstream in an apparatus and concluded that the law of the relationship of heat to air can be arbitrary but the integral performing the work must be taken in terms of a closed contour in the coordinates  $p$ - $v$  representing the change in the state of the air passing through the apparatus. /10

Thus, the thermal efficiency of the heat cycle undergone by air in a jet engine during its contact with air there was immediately determined. The full

efficiency of the jet engine was found to be a product of the thermodynamic efficiency and engine efficiency or, as it is now usually called, "motion efficiency" or "propulsive efficiency."

At the end of the lecture Boris Sergeyevich gave a quantitative definition of the full efficiency of an air-breathing jet engine for flight speeds of 50 to 600 m/sec powered by hydrocarbon fuel with a coefficient of air excess of  $\alpha = 2$  and thermal cycle efficiency of  $\eta_t = 0.25$ .

In addition, he showed how the efficiency for the air-breathing jet will be determined if energy is supplied to the air either partially or fully, and he examined the case of the compression of the air stream from losses of the kinetic energy of the incoming flow. In this case the air describes the "Brayton cycle" and its thermal efficiency will equal the difference between unity and the temperature-air ratio at the end of compression to its initial temperature upon entry into the jet engine.

Word of this lecture quickly spread among the top scientific and engineering brainpower then interested in rocket theory, and Stechkin was invited to repeat his lecture before a larger group.

Such a lecture took place soon after in one of the large auditoriums of the House of the Soviet Army. The hall was overflowing, and many wishing to enter could not. Then Boris Sergeyevich was requested to publish his lecture. And so, at an extraordinarily fast pace, with the aid of Stechkin's students, the lecture was polished and on its basis Boris Sergeyevich prepared for press the article "The Theory of the Air-Breathing Engine, ." It was first published in February 1929 in the journal "Tekhnika Vozdushnogo Flota (Air Force Engineering)" and thus became the property not only of us in the USSR, but of those in other countries as well.

This article was the first time that the equations of thrust for a jet engine were published:

$$R = m (v - v_0) + f (P - P_0)$$

$$R = m (v - v_0)$$

Clarifying the principles of operation of the air-breathing jet engine, Stechkin wrote:

/11

"Force R, which we will call the free thrust of the reactive engine, will thus be the equivalent force of air pressure on both the internal and external surface of the jet engine."

The article gave the equation for engine efficiency:

$$\eta_e = \frac{RV_0}{Q_0} \quad A = \frac{2V_0}{V + V_0} \eta_t$$

and stated:

"As may be seen, the efficiency of the reactive engine equals the product of two efficiencies, one of which is the thermal efficiency of the air cycle and the other is the efficiency of a propeller moving with speed  $v_0$  and throwing behind a stream of air with absolute velocity  $v - v_0$ ."

Further in the article the following expression for the efficiency of the air-breathing engine was given:

$$\eta_e = 2\eta_t / \left( 1 + \sqrt{1 + \eta_t \frac{2gQ_0}{AV_0}} \right)$$

The theory of the air-breathing engine developed by Stechkin pertained not only to the ramjet but to engines with compressors as well. In the article quoted it was written:

"If there is contact with external forces when the air passes through the engine, the efficiency has the form:

$$\eta_e = \frac{RV_0 A}{Q_0 + AT_0}$$

where  $T_0$  is the force spent outside for the contact with each kilogram of force of air equal to  $T$ ."

Shortly after Stechkin's work was published, the foreign engineering literature referred to it and acknowledged unanimous recognition of the Soviet supremacy in this field. Thus, for example, the well-known Italian scientist in hydrodynamics Arturo Giovanni Crocco in his essentially new work "Superaviation and Hyperaviation," published in 1931 in "Rivista Aeronautica" had to acknowledge that the classical theory in air-breathing engines was due first to Soviet Professor Boris Sergeyevich Stechkin.

Stechkin supplemented his remarkable contribution to the development of jet engineering, as was indicated earlier, by much pedagogical work. Passing 12 his knowledge on to hundreds of young specialists, Stechkin furthered the wide introduction of works on jet engines to the industrial design offices, research institutes, test stations and other organizations. Abstracts of Professor Stechkin's lecture, which he read at Moscow's Bauman Higher Technical Institute, in the N. Ye. Zhukovskiy Air Force Academy, and at special engineering-design courses on rocket technology, served as the theoretical manual for the design of air-breathing engines.

In the early 1930s, the editorial staff of the paper "Za industrializatsiyu (Industrialization)" organized another lecture by Boris Sergeyevich Stechkin on this same theme in his quarters on Tsvetnoy Bul'var in Moscow.

Thus, the theory of the air-breathing engine created by B. S. Stechkin began its full life and permeated many design offices specializing in this realm as well as scientific research and planning organizations.

Now we are witness to the wide use of large craft powered by jet engines such as the airliners of A. N. Tupolev, passing through the air above our planet at incredible speeds, and the value of B. S. Stechkin's theory is more and more understood.

I personally see broad horizons for these engines not only in aviation, but also in rocket technology--and their use in the first stages of ballistic missiles and, as was brilliantly predicted by F. A. Tsander in his day, on winged rockets.

Already the first calculations and studies of their application to rockets indicate that the value of various complex engine structures has caused a substantial drop in the initial launch weight of the rocket and on-board fuel reserves, which is especially desirable for large carrier rockets lifting heavy craft into orbit.

SUPPLEMENT TO THE THEORY OF ACADEMICIAN B. S. STECHKIN  
ON THE CREATION OF RAMJET ENGINES

M. M. Bondaryuk

№ 68 - 13569

The development of engine installations for aircraft in the last 15 to 20 /13 years has been characterized by spasmodic processes. In a relatively short time there occurred the formation, blossoming and decline in the development of various types of air-breathing engines (piston, pulse jet, turboprop, turbojet and ramjet).

The ramjet encompasses the widest range of application in terms of flight speed and altitude. It is well-known that as flight altitude increases and is accompanied by a drop in atmospheric pressure, conditions for carburation and fuel consumption in the combustion chambers of air-breathing jets degenerate. On the other hand, with an increase in flight speed through the use of high-speed pressure heads for the inflow, there is a pressure increase in the combustion chamber. Therefore, the greater the flight speed, the higher the altitude at which combustion can satisfactorily occur. And because the ramjet is capable of developing the highest speeds, it can operate at higher altitudes than any other type of air-breathing jet engine. Therefore, supersonic and hypersonic ramjets are being given the greatest future in today's world literature for being the engine most capable of powering winged aircraft. These same engines can be effectively used for wingless rockets as well for the power source of the second stage (ref. 4).

If winged flight is considered at top speed for relatively long periods, the only solution to the problem is use of the ramjet.

The development of ramjets is affected by the fact that with increase in flight speed, the air-breathing jet engine has difficulty and the optimal values of pressure increase in the compressor must be lowered. Thermodynamically, the use of the turbojet is reasonable when pressure behind the turbine is greater than that in front of the compressor.

Theoretically, the degeneration of the turbojet occurs at Mach 4, at which /14 point the optimal degree of pressure increase equals unity. The actual flight Mach number determining the danger point for a turbojet of usual design will hardly increase the Mach number  $M = 3$  significantly and will depend on the degree of perfection of the engine parts and the overall design and engine structure.

Ramjet engines have already been used successfully in various aircraft. Examples are the Bomarc missile, which has been thoroughly described in the press; the long-range anti-aircraft guided missiles: Bloodhound, Telos, Vega, Matra, etc; winged rockets for ships and shore targets--Typhoon, etc; the supersonic drone aircraft: Lockheed Kingfisher, Beechcraft, Aeronca, Nord Aviation ST-41, etc.

This beginning of a wide practical application of ramjet engines is explained by their intrinsic advantages over other types of jets. Along with the ramjet's many basic advantages and its already mentioned capability of operating at very high flight speeds and altitudes, there is also its greater economy over

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the liquid-propellant rocket engine as well as its light weight, lack of moving parts and simple construction.

These properties have determined the ramjet's range of application; it is the most effective engine for high-speed aviation.

The limits of operation of the ramjet are functions of the flight speed and altitude. Altitude is determined by the Mach number and is the minimum required for the functioning of pressure in the combustion chamber. The maximum Mach number at which the ramjet can operate practically has not yet been established. In a very significant way it depends on the degree of dissociation of combustion products, on new types of fuel (alkyl boranes and hydrogen) and on the principles of organization of the operating process (combustion at Mach 1). With a significant increase in the Mach number, additional heat supply does not cause a great increase in gas temperature, because the energy is expended in the dissociation of combustion products.  $\text{CO}_2$  and  $\text{H}_2\text{O}$  molecule fragments appear in the combustion

and discharge products. It must be noted that in any given case the effect of dissociation is contradictory. Being a negative effect causing disintegration of molecules and consequently a drop in temperature, dissociation at the same time is not an absolute loss, because recombination occurs during expansion and /15 escape of the products of combustion. At high flight speeds and consequently at high dynamic compression, recombination of the products during escape almost completely eliminates the deleterious effect of initial dissociation. Because energy expended in dissociation is freed during recombination, the escape velocity of gases increases. Consequently, at high Mach numbers dissociation limits the combustion temperature ( $T = 2800 - 3000^\circ \text{K}$ ), which is favorably shown in the combustion chamber stability, and with this causes a considerable supply in heat energy, which is manifested by recombination in the nozzle sleeve. It is of course necessary to consider the slight decrease in the heat efficiency of the overall process, because the heat supply in the nozzle sleeve occurs at decreased pressure.

As has been stated above, the great advantage of the supersonic ramjet is its small specific weight. It is interesting to observe how weight is distributed among ramjet parts. In one engine with an overall weight of 140 kg, 40 percent was for the combustion chamber and nozzle, 34 percent for various components and 26 percent for the diffuser. It must be noted that the diffuser has a long duct

necessary only for mixing. The specific weight of this engine is  $0.2 \frac{\text{kg wt}}{\text{kg thrust}}$

at altitudes of  $H = 18 \text{ km}$  and totals  $0.02 \frac{\text{kg wt}}{\text{kg thrust}}$  for  $H = 0$ .

The idea of the use of jet engines on aircraft was expressed in the 1840s by the Russian engineer I. I. Treteskiy and in the 1860s by M. N. Sokovninyy. N. Ye. Zhukovskiy, in his works, comprehensively investigated the full reaction of escaping fluids and evolved a formula for determining the efficiency of the reactive engine.

Another great Russian scientist, K. E. Tsiolkovskiy, developed a theory of rocket flight with variable mass and derived a series of basic equations for the dynamics of rocket flight and proposed structural diagrams for rockets. In his works, he devoted special attention to liquid-propellant rocket engines. He also developed a diagram for an air-breathing engine.

In 1929, B. S. Stechkin's work "The Theory of a Reaction Engine," appeared. In it he gave the first calculations for various types of jet engines. After this, there appeared experimental and theoretical studies of the operation processes of ramjet engines, theoretical investigations of their use on aircraft, and finally attempts for their practical application. /16

In the Soviet Union the idea for a ramjet engine was first applied by Yu. A. Pobedonostsev and M. S. Kisenko, who used a 76-mm artillery shell for the object and phosphorus for the fuel. Their tests obtained a notable increase in the distance of the shell's flight. This work is the first test of the practical use of the ramjet engine.

In 1939, the engineer I. A. Merkulov built and flight-tested a rocket with subsonic ramjet engines, and then aircraft ramjet engines for use as boosters for production aircraft.

In 1942, this author and G. A. Varshavskiy conducted similar tests on the LAGG-3 aircraft, which showed the practical workability of ramjet engines along with a whole group of faults which had to be eliminated to permit normal use of the engine.

Ramjets are characterized by the creation of the operating pressure in the combustion chamber through braking of the fast thrust of air entering the aircoop. Fuel combustion in the chamber occurs at almost constant pressure.

A natural intrinsic deficiency in ramjet engines is the lack of takeoff thrust and a poor economy at low flight speeds. For takeoff of ramjet-equipped aircraft the use of some takeoff device is required.

Ramjet engines may be divided into two basic groups: a) acceleration, and b) sustainers.

Acceleration engines are intended for the acceleration of rockets or aircraft and are designed such that they will yield maximal thrust within a wide range of Mach numbers and flight altitudes. Consequently, the acceleration engine must have a diffuser with sufficiently broad characteristics within a wide range of Mach numbers, a combustion chamber with minimal hydraulic resistance and increased thermal stability for operation at limiting thermal-stress operation regimes. As a rule such an engine has a large relative critical cross-section ( $f_{cc} = 0.9$ ) for the nozzle due to the rocket's requirements of maximum booster heating. It operates between Mach numbers from 1.5 to 5. Operation time is usually not great. /17

The sustainer engine is intended for winged-rocket flight or aircraft flight at constant speed over more-or-less long distances. Maximum economy is of course demanded of such an engine. The engine has a diffuser operating within a narrow range of Mach numbers but with high performance, a combustion chamber of mean thermal stress with thorough fuel combustion, and a Venturi-type expansion nozzle in which the basic transformation of potential and thermal energy of the flow into kinetic energy occurs.

There are acceleration/sustaining engines used on craft which must first attain acceleration to definite speeds and then maintain constant-speed sustained flight. This type engine has a so-called "compromise" diffuser, i.e., one capable of operating with high performance over a somewhat narrower range of Mach numbers than the acceleration engine, but which in return offers fairly good performance for sustained flight. Such an engine has less maximum thrust than the acceleration type and less economy at cruising flight than the sustained.

The combustion chamber of such an engine must operate with a wide range of mixture compositions. The engine has a Venturi-type expansion nozzle capable of operation at high booster heating.

If the acceleration/sustained engine must offer maximum thrust and economy parameters characteristic of both types engines separately, a controlled diffuser and nozzle with variable critical opening must be used.

The basic element of the ramjet engine is its combustion chamber, where the chemical energy of the fuel is transformed into the thermal energy of the gas flow, which within the limits of the combustion chamber partially succeeds in transforming into kinetic energy of the gas jet. The combustion chamber is a high-performance heating arrangement capable of consuming tens of kilograms of hydrocarbon fuel per second. Fuel consumption occurs at high air-flow speeds reaching 150 m/sec and pressures reaching several atmospheres. It is natural that the combustion chamber must have a powerful stabilizing setup supporting constant combustion as well as devices assuring reliable ignition. /18

The combustion chamber must have a high fuel combustion ratio and minimum hydraulic resistance within a rather wide operation range with respect to mixture composition.

The high values for completeness of fuel combustion are attained by logical fuel distribution throughout the chamber, the positioning of the high-temperature local combustion focus, usually in the center of the combustion chamber, and an effective system of annular and radial structures for flame stabilization. The combustion chamber must have the required length within the limits of which thorough combustion of the fuel with a prescribed completeness occurs. The operation range of the combustion chamber depends on the demands made on the engine during operation. Thus, if the engine is an acceleration type, maximum thermal stress conditions exist in the combustion chamber which are characteristic of the combustion process with a coefficient of air excess of  $\alpha \approx 1$  and high pressure in the operating body. In this case the so-called single-circuit setup is selected in the combustion chamber in which conditions with mixture composition of  $\alpha \approx 1 - 2.2$  may be realized.

If the engine is a sustained-operation type it must offer maximum economy, and consequently the combustion chamber must operate at relatively weak mixture contents ( $\alpha = 2.0 - 3.5$  with respect to the cruising flight Mach number). In this case the combustor is double-contour. The internal contour operates on mixtures close to stoichiometric, and the outer contour is passed by the remaining portion of the air which when mixed with the internal heated combustion products creates the necessary limits of operation with respect to mixture composition.

The acceleration/sustained engine must have the properties of both types of engine; developing this type of engine is therefore quite a challenge.

Let us concentrate on several actual ramjet engines.

In 1948, the single-contour subsonic acceleration/sustained engine was created for use as a booster on the La-9 aircraft.

Two ramjet engines were suspended from the aircraft's wings and set into operation by the pilot. The engines operated within Mach ranges from 0.4 to 0.85 and generated 320 kg thrust at rated altitudes. The engine's specific thrust /19  
under various regimes was  $520-650 \frac{\text{kg}}{\text{kg/sec}}$ .

The ramjet engine yielded a maximum relative increase of 110 km/hr in the speed of the La-9 and could be fired repeatedly. Its dry weight was 40 kg.

Presently the scientific literature (refs. 3, 6, 7, 9) is devoting more and more attention to hypersonic engines, i.e., ramjets capable of operating at high supersonic speeds ( $M > 5$ ). The interest in hypersonic engines is due to their capability of operating within a wide range of Mach numbers without control of the flow-passage cross-sectional areas of the engine. Of course, the usual supersonic ramjet engines are capable of operating within wide Mach number ranges; to do so their flow-passage areas must be controlled during flight, which is rather complicated.

The main advantage of the hypersonic ramjet is that heat supply to the air in the combustor occurs at supersonic flight speeds. Consequently, the hypersonic engine has no critical sections in its channel. This leads to the fact that the hypersonic ramjet engine, having an unregulated diffuser and venturi, can operate within much wider ranges of flight speeds and mixture compositions than the supersonic. Heat supply to the supersonic flow in a cylindrical tube is known to be accompanied by an increase in the static pressure of the flow and a drop in Mach number, i.e., a restriction of the temperature regime of the hypersonic engine for Mach 1. With additional supply of heat there is a decrease in the air consumption through the engine and a disruption of the system of shocks at the diffuser intake.

At first glance it appears strange that such relatively high performance can be expected of the hypersonic engine when it is well-known that with an increase in the flow velocity, losses in full pressure when heat is supplied increase sharply, while the ratio of pressure reduction is extremely small in the hypersonic diffuser.

However, it must be kept in mind that for high flight speeds, air compression in the compressor is so great that even high pressure losses lead to a relatively low decrease in the escape speed from the venturi.

Therefore, the hypersonic engine has relatively high performance within a wide range of Mach numbers. /20

There may be two setups for the hypersonic engine.

The first, with a central air-intake body, an annular combustor and a venturi limited by its "fluid" contours, has many advantages over the second setup, in which the diffuser is a reversible Laval nozzle and a nozzle with "rigid" walls.

First, in the first arrangement conditions for the start-up of the diffuser are facilitated; second, losses to drag naturally decrease due to the existence of two "fluid" walls; third, cooling of the diffuser and nozzle walls is facilitated because their surfaces are substantially smaller in the first arrangement.

As can be seen, the design of the hypersonic engine in no way differs from similar setups for usual ramjet engines, but the processes within the engines have many characteristics related to the existence of a supersonic flow in the combustion chamber.

The difficulties in designing a hypersonic engine are obvious: high engine body temperatures due to high flight speed, special arrangements for fuel distribution, flame stabilization in supersonic flow, shielding the combustor and nozzle walls from high-speed, high-temperature gases.

However, the properties of hypersonic engines are satisfactorily high. It is well known, for example, that for a hydrogen propellant the specific thrust is several times that of liquid-propellant engines. With hydrocarbon fuels it is lower than hydrogen but still substantially higher than liquid fuels (ref. 9).

The range of application for hypersonic ramjet engines is substantially broader than that of supersonic engines.

Thanks to its simplicity and relatively low cost, the hypersonic engine may find wide use in Civil Aviation aircraft (ref. 6).

Hypersonic engines may also be used for control of spacecraft on takeoff into the atmosphere and for spacecraft returning to Earth.

Recently the foreign press carried reports of the possibility of using ramjets as the second stage of ballistic missiles (refs. 9, 10, 11). This would permit using the thirty-kilometer air layer through which rockets pass, all the more because the economy of the ramjet engine at these operation regimes is three or four times that of rocket engines. /21

The examples cited are convincing proof that the theory of the air-breathing engine created by Academician B. S. Stechkin is presently being widely developed by scientists of many countries around the world.

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THE FIRST EXPERIMENTAL INVESTIGATIONS OF RAMJET  
ENGINES BY "GIRD"

I. A. Merkulov

The theory developed by B. S. Stechkin opened the way to practical work in the creation of air-breathing engines, which began in our country. When GIRD (Group for the Study of Jet Engines) was organized, one of its teams, headed by Yu. A. Pobedonostsev, carried out the first studies of air-breathing engines. Pobedonostsev allotted several months to theoretical calculations and working out the problem of the possible areas of application of these engines. Then came the time to proceed to practical work--the study of models and individual engine components. /22

In March 1933, a test apparatus designated IU-1 was constructed for accomplishing these investigations. Its first test was on 26 March. A compressor setup designed for feeding compressed air to the receiver, from which it was to be sent to the test model, was checked out. The first official report of the tests in this new realm of technology--air-breathing engines--has come down to us. The report briefly stated:

"At 2 hrs 30 min in the morning, the switch for the electric motor setup was thrown."<sup>1</sup> The first test lasted fifteen minutes. Manometers showed that the air pressure beyond the fourth and last stage of the compressor reached 100 atmospheres. On the second test it reached 190 atm. Through the support of the whole GIRD group, the testing and improving of the installation progressed and after six tests it was prepared for tests of the engine model. The third group was presented the mission of the tests: "The development and investigation of the operation of an air-breathing engine with a gas fuel."

Early in the morning of 15 April 1933, the first test of the engine took place.

"The first firing of the engine completely fulfilled theoretical predictions of air-breathing engines with gas fuels. /23

"This test has initiated experimental investigations of air-breathing engines.

"Four days after the first test, the next one was carried out on the IU-1 setup. This time the engine's operation was tested for various combustion-chamber temperatures from 0 to 3.2 atm. During the test, the engine was started three times, and it was established that 'in normal engine operation, ignition is required only at the start. After that, as the combustion chamber is heated, ignition can be stopped and power controlled through fuel and air supply'."

Proportional to the testing of the models of the air-breathing engine, investigation methods were gradually improved. Beginning 9 July 1933, tests on

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Here and later GIRD archive documents are quoted.

the IU-1 setup included measurements of the thrust generated by the test engine.

To render the engine effective not only at supersonic speeds but at subsonic as well, Pobedonostsev sought engines having air compression aided by some arrangement in addition to air compression in the diffuser resulting from the kinetic energy of the air flow. One such arrangement was the pulsejet.

To test the possibilities of creating pulsejets, an experimental valve-equipped combustion chamber designated EK-3 was set up at GIRD in June 1933.

Somewhat later that year, the idea arose at GIRD of increasing the pressure of the effect of the gas jet flowing from the liquid fuel in the diffuser. The speed of the gas escape from the liquid-fuel nozzle, as has been indicated by earlier calculations, can reach 3000 to 4000 m/sec. Therefore, if a small rocket engine were to be installed in the diffuser, the gas jet escaping from it could inject air into the combustion chamber, increasing pressure in it.

This engine design was found reasonable, but due to the great complication and difficulty of constructing it in those years, its experimental study was put off until a later time.

The 1933 GIRD tests of the pulsejet brought to light the basic problems involved in the structural development of such engines, and permitted evaluating the difficulty of their solution. In the following years it was decided to concentrate all attention on studies of ramjets. Later studies of pulsejets and injection engines were carried out at RNII (Jet Engine Research Institute) in 1936-1939.

### Preparation for Flight Tests

Experimental operations in the study of ramjets were begun at GIRD in April 24 of 1933 and continued all year. Successes in the first experimental investigations made it possible to proceed to flight tests of the ramjet. Yu. A. Pobedonostsev had the bold idea of setting the engine under study in an artillery shell and performing tests at supersonic speeds, i.e., precisely the range where the ramjet engines are the most effective. The possibility of creating a ramjet engine, which still had not been constructed anywhere in the world, had to be experimentally proven. The correctness of theoretical propositions had to be proven in practice. It had to be proven that an engine of this type could actually generate thrust. In those years, when the question still existed as to whether it was generally feasible to create a ramjet engine, the only valid answer could be given by an operating engine demonstrating its ability in flight.

The choice of fuel for the engine was highly significant. As a result of careful examination of all operating parameters for the engine during the proposed tests, the following basic demands were set to its fuel: (a) it should be solid, (b) it should be easily ignited and have the property of high-speed combustion within a wide range of mixtures with air, and (c) it should have the required heating power per liter.

Having considered a large number of fuels, Pobedonostsev selected white phosphorus as one of the most suitable for the first tests.

As later progress showed, the selection proved quite fortunate. It was also decided to use a gasoline-based solid as a fuel. Therefore, the planned use of the engine in an artillery shell permitted the possible use of either phosphorus or gasoline.

In preparation for flight tests, a special portable carriage was constructed in which the engine combustion chamber was installed.

On 12 July 1933, at one of the firing grounds outside Moscow, the first tests of the phosphorus-fueled combustion chamber were held. This combustor received the designation EK-4. The aim of the first tests was to study the properties of phosphorus as a fuel for reaction engines and particularly those set in /25 artillery shells, which received the designation 08 hardware.

The tests were completely successful. In a short time--10 to 20 seconds after firing air into the combustion chamber, the phosphorus self-ignited. Combustion lasted until complete burnout of the phosphorus grain. There was no fusion or flow discharge of liquid phosphorus from the nozzle.

At the conclusion of these tests, it was stated that:

"Tests have shown that phosphorus can serve as a fuel for the second model.

"Containers for holding the phosphorus grains should be iron, as those of copper are quickly destroyed."

The aim of subsequent tests was to study the combustion of phosphorus in the combustion chamber with high flow rate of air and clarify the possibilities of using a gasoline-based solid as fuel for the 08 hardware.

During the tests, the combustor with phosphorus grains was fired twice, once with air pressure of 4 atm in the receiver and again with 1 atm pressure. Phosphorus combustion was interesting, especially in the first case. With a sharp increase in pressure in the reverser, combustion subsided briefly, after which the flame again appeared. Full burnout of the phosphorus grains took approximately 1 minute.

During these tests, firing took place with small fragments of phosphorus placed in the axial duct of the EK-4. Air pressure in the receiver was below 1 atm, so that the air consumption was relatively low. It was also decided to investigate a fuel mixture of phosphorus and gasoline-based solid.

In July 1933, powder ignition adaptations were tested repeatedly to develop a more reliable means of firing the fuel in the combustion chamber.

These tests established that powder adaptations can provide reliable ignition of fuel in the combustor. As a result, this idea of Pobedonostsev for using gunpowder for firing the fuel in the ramjet found a practical application in several versions of these engines.

In July 1933, seven tests were run, two of the VRD-1 (Air-breathing engine) and one of an engine with conic combustion chamber operating on ethylene. /26 The tests were to study carburation, ignition and combustion of the fuel-air mixture. During these tests even combustion was achieved, which showed the practicality of using not only hydrogen but hydrocarbon fuels. Twelve pounds of thrust were achieved.

All the second half of 1933 was spent preparing for flight tests of the engine.

Thanks to the solid friendly work of the small group of the third GIRD section, all test-stand studies and preparatory work opening the way to the beginning of flight tests were soon carried out. And in the autumn of 1933, the air-breathing engines underwent the world's first flight tests.

### The Air-Breathing Engine in Flight

The ramjet engine designed by Yu. A. Pobedonostsev had the external conformation of a long-range 76-mm cannon shell (Standard 0124). The internal portion consisted of an intake duct, combustion chamber and nozzle. The fuel grain was located directly in the combustion chamber. Before firing from the cannon, to avoid the rupture of powder gases into the engine, the exhaust nozzle was covered with a metal block. After the engine was fired from the gun, the block separated from the shell and fell not far from the gun.

The first model of the shell also had an allowance for a payload.

The fuel grain was a metal shell filled with white phosphorus. For air to pass from the diffuser to the combustion chamber, and to aid fuel combustion, within the grain and along its axis there was a conic space set with the wide end toward the exhaust nozzle. To avoid premature self-ignition during transport and preparation for the tests, the phosphorus grains were covered by a thin film of lacquer.

The longitudinal ribs of the grain's metal case were of 2-mm sheet steel, and the transverse plates were of sheet Elektron which, it was assumed, would heat along the phosphorus and substantially raise the overall heating power of the grain.

Ten shells were set up for the tests. The testing was carried out with a 1902 model 76-mm gun at 20° elevation. The mean initial velocity of the shell was 588 m/sec. /27

Before firing the engine-equipped shells, two shots with modernized shrapnel were fired. The shrapnel fell at a distance of 7200 m. Then No. 1 shell was fired without fuel. Instead of the phosphorus grain, a grain case with sand having the same weight was set in its combustion chamber. The flight of this shell was accompanied by a strong whistle. Its flight covered 2000-3000 m. Then nine shots were taken with engine-equipped shells.

The results of these first tests corroborated the possibility of using artillery cannon for launching the engines; the test proved the full reliability of firing with shells of normal construction.

In all cases the fuel did not fail to ignite once in the combustion chamber. Ignition occurred approximately 10-15 m from the gun.

The flight tests of the air-breathing engine in September 1933 showed graphically that an engine of this type was workable. The graphic proof of this was the increase in flight distance for an engine-equipped shell (No. 3) to almost 1 km in comparison with the flight distance of a regular shell. This increase was obtained in spite of the fact that aerodynamically a missile with an open-through duct is considerably poorer than a typical shell, and consequently in the part of its trajectory where the engine was shut down the engine-equipped shell encountered more air resistance than the normal shell. In all cases, shells with operating engines flew farther than those of the same weight and shape but not powered. The sole explanation for the increase in flight distance is that the engine generated some in-flight thrust.

This fact had a great intrinsic value. The results of the flight tests not only established that the air-breathing engine functioned, but indicated the amount of thrust it generated. From preliminary calculations the force of air drag the shell experienced and the thrust force the engine generated were all determined. At flight speeds of 588 m/sec with which the missile left the cannon barrel, the calculated amount of air resistance was 20 kg, while engine thrust at the same speed was 10 kg, i.e., somewhat less than the air resistance. 28 Consequently, the engine was capable of compensating 90 percent of the air drag, but could not fully overcome it and accelerate the shell. Because drag exceeded engine thrust, the shell's speed should have decreased in proportion to the flight duration. A decrease in velocity led to still greater increase in the difference between drag and thrust. Thus, both at the moment of escape from the cannon at a determined initial velocity and in subsequent flight, the calculated engine thrust was less than the drag. This fact in no way confused investigators, because the flight tests were intended to establish the air-breathing engine's operation and determine the degree of approximation between actual thrust and calculated.

Evaluation of results showed that actual air drag exceeded the calculated, and thrust was somewhat less than calculated. This had several reasons: deformation of the metal shell of the phosphorus grain, insufficient in-flight stability, etc.

The explanation for the decrease in thrust relative to calculation and the increase in drag was a valuable result of the first series of tests. With the causes of these flaws in the engine's operation found, it remained to seek means of eliminating them in improving the engine.

After the first series, a second series was conducted in February 1934, and a third in 1935 in which six more models of the engine were planned for the 76-mm shell. Several models each incorporated several groups differing in the intake section dimensions of the diffuser or the critical nozzle throat. Some models differed in fuel supply.

The second model differed from the first only in the structure of the phosphorus grain. To decrease buckling of the longitudinal ribs in the body it was decided to allow the grain to rotate freely in the combustion chamber. With this type of construction of the grain, increase in the angular speed of the grain would not occur immediately, but gradually, which could obviate buckling in its ribs.

Thanks to improvements introduced into the construction of the engine, test results of the second model were noticeably better. The highest value for specific thrust obtained for the shell with  $\alpha_{cr} = 35$  mm was 320 kg/sec per kg of /29

fuel. This was 43 percent of the calculated value (750 kg · sec/kg). A decrease in the amount of specific thrust by comparison to the calculated value is explained first by the ejection of incompletely consumed phosphorus from the engine in the first moment of flight. Observation of the missile's motion permitted us to establish that when the missile left the cannon barrel, a substantial quantity of phosphorus incompletely combusted in the air fell out as a result of separation of the bottom cap. This occurred apparently because the particles of solid phosphorus fell from the shell and were scattered by the air jet from the engine as the missile left the barrel at high velocity (around 300,000 m/sec<sup>2</sup>). Later, when positive acceleration disappeared and negative was thousands of times less due to drag, the phosphorus no longer fell from the engine because centrifugal force threw it to the combustor walls.

To eliminate fuel losses, the third model had the grain body prepared in such a way as to lessen the loss of phosphorus. In addition, phosphorus with a lower combustion temperature was used. Through improvements in the fuel grain in engines of the third model, the amount of specific thrust rose to 423 kg · sec per kg of fuel.

In these engines, the fuel grain fulfilled its purpose of supporting the phosphorus during the launch period in the cannon and then was used as fuel. Therefore, tests of this group of missiles were quite significant. Prior to them, the interesting ideas of Tsander and Kondratyuk concerning the use of a metallic fuel in jet engines were developed only theoretically or in experimental tests on stands. The engines designed by Pobedonostsev were the world's first to operate in flight on a metallic fuel not in the form of a powder, but as a structural element.

The second group of engines of the third model was prepared with larger air scoops. The diameter of the intake section was increased to 30 mm. To test the new type of engine as fully and thoroughly as possible, shells were prepared which had not only grains with Elektron bodies, but some grains with no bodies. Here it was known that phosphorus ejected in the first moment of flight would increase substantially, but the price lowering drag, the source of which was the incompletely combusted remains of the metallic grain body, was the loss of some fuel. It was interesting to note which of the factors was more important and which shells flew farther. Engines of all three of the following models--fourth, fifth and sixth--were prepared with bodyless grains. In grains of the fourth model, the diameter of the axial duct was 15 mm, i.e., less than that of the intake section of the air scoop. In this model, the weight of the grains

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was increased to 645 g as against 270-300 g in earlier models. In the next two models, grains with larger-diameter ducts were used. Due to this, the weight of /30 the grains in the fifth model was decreased to 400 g.

In the sixth model the phosphorus supply was again increased, to 620 g, by placing it where the payload would be. Missiles of the fourth, fifth and sixth models reached 12 km.

Tests showed that in engines installed in shells with small dimensions it was difficult to achieve combustion with full burnout. This fact spurred construction of an engine for a six-inch shell. Such a shell with an air-breathing engine was planned and designated 14, but was not tested.

Tests had yielded a sufficiently high efficiency, reaching 16 percent at best. If we consider that a substantial portion of the fuel was dropped from the engine in the initial moment of flight, the actual amount of efficiency would be substantially greater.

The ratio of thrust to drag was approximately as follows. According to calculation data, at the moment of exit from the cannon barrel at 680 m/sec, the missile underwent drag equal to 25 kg. Engine thrust was 30 kg. In practice, at exit, drag acting on the shell with the engine shut down was 42 kg. Thrust after exit from the cannon was 23 kg. Consequently, thrust compensated for more than half the drag. With the engine functioning (in spite of the force of gravity), the braking force of air drag was not 42 kg but only 19 kg. Due to this, flight distance was increased.

A concise recapitulation of the results of the first tests with ramjet engines shows that even early in the development of rocket technology, with very /31 limited experimental capabilities, scientists strove to study the operation of this new type of engine more widely and to grasp the principles controlling the processes operating in them.

The decisive result of these tests accomplished by success begun in GIRD's work on air-breathing engines was the experimental proof of the workability of these engines. The basic question--would the ramjet engine operate--received a clear answer: yes, the ramjet engine, created on the basis of B. S. Stechkin's theory, was capable of operating in flight and generating thrust. This was the important conclusion.

One more fact of historical importance must be noted. The ramjet engines of Yu. A. Pobedonostsev's design were the first jet engines which broke into the supersonic range. The shell with the air-breathing engine operated at a speed double that of sound. No rocket in the world had previously attained such a speed.

Flight tests of shells with ramjet engines were conducted by a group headed by Yu. A. Pobedonostsev which included: M. S. Kisenko, A. G. Salikov, A. N. Ryazankin, G. V. Shibalov, I. A. Merkulov, L. E. Bryukker and O. S. Oganessov.

Because experiments supported the idea that such engines could function, the theoretical conclusions of B. S. Stechkin and F. A. Tsander and foreign scientists including especially the Italian Academician Crocco concerning the expediency and great effectiveness of ramjet engines on various aircraft were consequently considered well-founded.

Now a second challenge--solving the problem of the practical use of ramjets on aircraft with scientific or defense purposes--loomed before the scientists.

The investigations carried out, while proving the workability of the air-breathing engine, at the same time showed that these engines generate relatively little thrust. In the first tests of the engines in shells, their thrust did not reach the amount of the drag on the shells tested.

Naturally the question arose as to whether the ramjet engine could generate 32 thrust exceeding drag experienced by the engine encased in a streamlined nacelle. This remained to be solved in the next stage of investigations.

## FIRING OF THE WORLD'S FIRST RAMJET ROCKET

V. P. Kaznevskiy

The flight tests of a supersonic ramjets designed by Yu. A. Pobedonostsev proved in practice that this type of engine generates a reactive force through which the flight distance of a ramjet-equipped shell was significantly greater than that of a regular shell. /33

Having proven the workability of the engine, the investigations also showed that these engines generate relatively little thrust, and in turn questioned the possibility of creating a ramjet generating thrust greater than the drag experienced by an engine body housed in a streamlined nacelle.

To solve this question the engineer I. A. Merkulov studied the ramjet thermodynamic cycle and for his first conclusion established that the ramjet engine operating according to the Brayton cycle, i.e., with combustion for  $p = \text{const}$ , cannot generate thrust greatly exceeding the drag it experiences, i.e., cannot in practice even to push itself, much less communicate acceleration to any type of aircraft. This arises because air in the combustion chamber of the ramjet must be heated to a high temperature to obtain the most thrust possible. However, while raising the gas temperature, maintaining constant pressure requires increasing the area of the cross section of the combustion chamber proportional to the increase in temperature. Therefore, with an increase in thrust the dimensions also increase, and consequently so does the amount of engine drag.

However, this negative conclusion did not hold back further tests of the ramjet. It was established that if we were to proceed on the basis of decreasing the thermal efficiency of the cycle, achieving fuel combustion at decreased pressure, it might be possible while losing some thrust to substantially reduce the engine dimensions and consequently decrease drag. Naturally, the question arose /34 as to how much the radial dimensions of the ramjet combustion chamber could be decreased.

It was necessary to select engine dimensions for which the free thrust, i.e., the difference between engine thrust and drag, would be greatest.

From the analysis of the heat cycles of the air-breathing engine, Merkulov selected the optimal engine parameters at which it could generate thrust significantly exceeding its drag. On the basis of these theoretical investigations, in 1936 he and a group of workers from the Jet Department on the Ts. S. Osoaviakhim Stratospheric Committee planned test models of the air-breathing engine. A. F. Nistratov, O. S. Oganegov, B. R. Pastukhovskiy, L. E. Bryukker, M. A. Merkulova, B. I. Romanenko, L. K. Bayev and others took part in the development of these engines. A large number of calculations for the theoretical investigations of the ramjet cycle were done by A. D. Merkulova.

Now the effectiveness of the engine's operation had to be verified in practice, in test flights, and the engine had to be proven capable of accelerating an aircraft in which it was installed. It was decided to run the first tests on

rockets. Therefore, the designers planned a rocket with a ramjet engine installed in the body. In the upper part of the rocket body, between the diffuser walls and the nacelle, a space was set aside for a parachute and payload.

The ramjet-powered rocket naturally might be tested only as a second stage rocket, while for the first stage some other type engine-equipped rocket such as liquid- or powder-propellant rocket might be required. For simplicity and reliability, it was advisable to use a powder-propellant rocket as first stage. Thus, a two-stage rocket was designed in which the first stage was a powder-propellant rocket and the second was an air-breathing rocket. All the GIRD tests were used in this design. As in the engines of Pobedonostsev, the air-breathing engine for the rockets used a solid propellant set in the combustion chamber as a grain.

The rocket design was completely examined by many scientists, who both approved it and supported the group working on it. It is interesting to acquaint ourselves with the conclusions of our scientists of a quarter century ago. Here is one: /35

"Conclusion concerning comrade Merkulov's draft plan 'A Rocket With an Air-breathing Engine.'

"Having acquainted myself with the proposed draft plan, I find it of great interest.

"1. This is the first use of an air-breathing engine for stratospheric rockets. Preliminary calculations permit concluding that the engine offers a significant advantage over the usual type of rocket engines for atmospheric flights.

"2. The firing method selected is the simplest and cheapest, both providing the required speed (to 300 m/sec) and permitting the assumption that the rocket will be stable in flight.

"3. The author's data are based on experimental (efficiency) data.

"4. I point out especially that the proposed plan is completely feasible in that the basic moments, namely (1) the operation of the powder-propellants engines selected for firing, and (2) the engine operation on several propellants proposed by the plan were successfully tested in practice. The draft plan developed by comrade Merkulov and the explanatory notes presented are sufficient to begin practical operation (finishing the planned project and beginning operations).

"In summary, I feel that the plan is quite feasible.

"Engineer Zuyev<sup>1</sup>"

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Documents quoted in this article are presently in the Scientific Archives of the Institute of History, Natural Science and Technology of the USSR Academy of Sciences.

Professor V. P. Vetchinkin, who regarded the plan for air-breathing rockets highly, wrote in his report of 18 January 1938:

"The main issue in question, in my opinion, has been very well resolved: by decreasing the area of the largest (third) cross section by several times compared to the theoretical, which was chosen for constant pressure in the combustion chamber, the author achieves his object of creating thrust stronger than drag, i.e., the engine's capability to fly independently. The essence of the plan was to resolve this.

"The simplest performance has been proposed for the first model--a rocket flying vertically, which is easily tracked.

"The calculated flight altitude is 26 km, which has not yet been attained by powder- or liquid-propelled rockets, even in calculations.

"The simple design promises cheap construction.

"It is absolutely necessary to construct several test models of the rocket of the proposed type and test them first on the ground and then in flight."

Professor K. A. Putilov carefully examined, tested and approved the thermodynamic calculations for the air-breathing engine and sanctioned work on creating rockets with such engines. Professor K. L. Bayev, who warmly supported the work /36 of the young engineers, greatly aided completion of ballistic calculations.

The support of outstanding scientists and leading specialists in the realm of rocket technology for the plan opened the way to realizing this plan. At one of the aviation factories, in the Special Design Department directed by A. D. Shcherbakov, work began in 1937 on the creation of air-breathing rockets. First, two engine models were planned which were intended to systematically investigate the processes occurring in air-breathing engines. To more quickly solve the basic problem of proving the feasibility of creating an air-breathing engine which would generate thrust exceeding drag and could propel an aircraft, a rocket designated the R-3 was planned. Solid grains consisting of a mixture of aluminum and magnesium powder with some additives were selected as propellant. Cylindrical grains with an open-through duct in the center were installed in the combustion chamber. Two types of propellant grains were set in the rockets. One, prepared by the Moscow State University (MGU) chemist V. A. Abramov, consisted of powdered aluminum and magnesium fixed by an organic filler. These grains were quite stable and were uniformly burned in the combustion chamber. The heating efficiency of the fuel comprising the grains was 4200 kcal/kg. The rocket's heat charge consisted of two grains with equal external diameter but with different diameters of the internal duct through which air passed from the engine diffuser to the combustion chamber.

Fuel consumption was aided by gunpowder ignited by a blasting fuze. Total weight of the propellant grain was 2.1 kg, and combustion time was 8 sec.

Other type grains were prepared in the D. I. Mendeleev Chemical Engineering Institute in Moscow under the direction of Abramov's scientific co-worker Der-gunov. They found a means to compress aluminium and magnesium powders under high pressure. To intensify the combustion process and increase engine thrust, a certain amount of oxidizer (potassium chlorate) was added to these grains.

Tests of the R-3 were conducted by a team consisting of engineer I. A. Merkulov, mechanics P. V. Karev and I. A. Charnyy, engine operator V. N. Akatov and chemist V. A. Abramov.

For flight tests, three series of rockets totaling 16 in number were pre- pared. /37

The technical data of the rockets (first series) are: weight of powder-propellant rocket--3.8 kg, weight of powder--1.4 kg, full impulse--260 kg/sec, maximum thrust--450 kg, average thrust--118 kg, combustion time for powder--2.24 sec, weight of engine-equipped rocket--4.5 kg, diameter of engine-equipped rocket--121 mm, full initial weight of two-stage rocket 8.3 kg.

Later models of the R-3 differed from those of the first series by some lightening in construction.

The first stage in tests of the R-3-2v were powder-propellant rockets with the following characteristics: full rocket weight--3510 kg, weight of powder--1050 to 1079 kg, gas escape velocity--1860 m/sec.

The first stage of the experimental operations was the aerodynamic testing of the rocket in a wind tunnel. In 1938 and early 1939 several dozen tests were run. Through these, the rocket's drag coefficients, the speed braking for powder-propellant rockets intended for the fastest release of the first stage from the second were determined.

Simultaneously, combustion tests in the combustion chamber were being carried out.

In February of 1939, flight tests of the engine were initiated at the air-field near the Planernaya station. The rocket was launched from a vertical launcher. The first tests dealt with launching, stage separation, and fuel combustion. The first successful flight clearly establishing the increase of rocket speed attributable to the operation of the air-breathing engine took place on 5 March 1939.

In two months--in the first days of May--tests took place presided over by the chief of the Special Design Department A. Ya. Shcherbakov, leaders of the invention factory V. V. Kol'tsov and P. M. Blayman, representative of the Zavkom (factory committee) S. M. Kumanin and others.

In two rockets tested that day, the propellant grains prepared by V. A. Abramov were tested. These tests clearly showed the reliability of all systems. It was decided to carry out official tests with the representatives of the aviation industry Narkomat (people's commissariat). For accurate determination

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of flight speed and lift altitude of the rockets, a team of astronomers headed by V. A. Bronshten was invited, and accomplished their task by using meteorite observation methods. /38

Official tests began 19 May 1939. Night was chosen so as to determine the rocket's movement through tracking the gases escaping from the engine against the background of the dark sky. A propellant grain prepared in the Mendeleyev Institute was installed in the rocket. After shutdown of ignition of the powder, the rocket flew from the launcher and rose. After separation of the first stage, the engine-equipped rocket clearly gained altitude. The rocket's successful flight was clearly apparent to those attending the test.

Data reduction by the team of astronomers established the following sample picture of the flight:

During firing of the first stage, the rocket reached a speed of 200 m/sec and a height of 250 m. After burnout of all its propellant, the first stage separated by an air brake installed in it. From the moment when the powder stopped burning until firing of the engine there was a lapse of about 2.5 sec. During this time, the rocket advanced 375 m, rising to an altitude of 625 m. The rocket's speed until this instant had been increased to 105 m/sec. At this flight speed, the ramjet engine was fired and operated 5.12 sec. Toward the end of the engine's operation, the rocket rose to 1317 m, reaching a speed of 224 m/sec. After burnout of the propellant, the rocket flew 6.06 sec on momentum and rose to 1808 m. By the end of engine operation, excess thrust, i.e., the difference between thrust and drag reached 20 kg, and the thrust coefficient was 0.7. Throughout the entire flight period with engines operating, the average speed was 23 m/sec<sup>2</sup>.

Test results of these, the world's first ramjet-propelled rockets, were established by a report which fully describes them. Let us explain that at that time terminology in the literature was not firmly established and the engines installed in rockets were called air-rocket engines and the rockets themselves, keeping in mind their use not only for altitude studies but defense purposes as well, were called wingless torpedoes.

"Report on the tests of the air-rocket engine.

"On 19 May 1939, at the airfield of Planernaya station (outside Moscow), the tests of the air-rocket engine designed by I. A. Merkulov took place. /39

"The object of the test was a wingless torpedo with an air-rocket engine.

"The engine's fuel composition was prepared at the Mendeleyev Chemical Institute.

"A normal powder-charge rocket was used for firing the torpedo.

"Ignition of the fuel and combustion of the powder-propellant rocket took place with the aid of an electrical fuse powered by a battery. A blasting fuze was introduced between the fuel and the electrical fuse to delay ignition of the mixture one second with respect to the fuse of the powder-propellant rocket.

The torpedo's flight altitude and speed were determined by a team of astronomers.

"The torpedo was mounted in a launch for firing.

"Firing took place at 22 hr 40 min. The torpedo's tests yielded these results:

"The torpedo flew vertically from the launcher. After 1 second, the powder-propellant rocket separated from the torpedo through a built-in air brake and fell below. At this instant the air-rocket engine began to operate. Behind the exhaust nozzle of the engine a trail of glowing combustion products formed vertically below. The engine operated evenly and continuously. The duration of engine operation in relation to the amount of fuel consumed was 5.5 sec. The beginning of engine operation introduced a strong increase in flight speed. With increased speed, the torpedo continued upward throughout the period of the engine's operation. After exhaustion of all fuel, the torpedo continued flight on momentum. The whole flight was stable and strictly vertical.

"The flight of the rocket has fully substantiated the reliable operation of the air-rocket engine and the increase in flight speed during its operation."

The tests of the rocket quite clearly demonstrated the rapid vertical flight of an aircraft with a ramjet engine.

These tests proved in practice the possibility of creating a ramjet engine capable of generating thrust exceeding drag and even the combination of drag and weight.

Thus ended the first stage of the work of Soviet scientists and designers in the creation of ramjet engines.

FLIGHT TESTS OF THE RAMJET ON AIRCRAFT  
DESIGNED BY N. N. POLIKARPOV  
IN 1939-1940

A. Ya. Shcherbakov

In the 1930s, work in rocket technology and the conquest of the stratosphere /40 was gaining momentum. Several stratospheric balloons were flown to altitudes of 22 km. In Leningrad in 1934, there was an all-union conference on the study of the stratosphere at the instigation of the USSR Academy of Sciences. The first successful flights of Soviet rockets with liquid-propellant engines were in 1933; 1934 saw the initiation of the work by the Jet Engine Research Institute created on the basis of GDL and GIRD. The first scientific and engineering conference on rocket technology was held in Moscow in 1935.

Scientific research and experimental design work broadened and was aimed at creating a stratospheric aircraft. In 1935, we introduced into the plan of these operations the proposition of launching a high-altitude towed glider, which in principle permitted piloted flights into the stratosphere to altitudes of 30 km and more.

To accomplish this, a Special Design Department (OSK) was organized at the Aviakhim factory where practical works and actual experiments were begun. Included in the tasks to be solved in attaining high altitudes and flight speeds were the problems of designing sealed cabins, jet engines, methods for carrying out such flights, etc.

Well-known specialists and designers were invited to OSK to partake in accomplishing these missions. They included the engineer I. A. Merkulov, with his experience and knowledge in the creation of reaction engines. It was first proposed that OSK would build an experimental aircraft with ramjet engine. This aircraft might be similar to the high-altitude towed glider we developed, then unhook from the towing system, switch to gliding and generate the high speed suitable for the operation of the ramjet. After ignition of the engine, the craft could fly independently, building up flight speed and altitude. /41

Engineer Merkulov was charged with completing the aerodynamic calculations and development of the design sketches of the ramjet-driven experimental aircraft. Simultaneous with the successful completion of these works, he designed two ramjet models for test-stand study as well as ramjet rockets which were flight-tested in March-May of 1939.

After the successful tests of the ramjet rockets, the Aviakhim factory OSK decided to direct future efforts toward the creation of an aviation ramjet for installation in an aircraft.

On 3 July 1939, at a conference of the NKAP (Aviation Industry People's Commissariat) Engineering Soviet, Merkulov presented a report on the results of experiments with ramjets on rockets and on the tasks of future study of the air-breathing engine, and improvement of its construction and its uses in aviation.

He proposed the use of ramjets in propeller-driven aircraft. The ramjets could be used as auxiliary motors for increasing maximum flight speed. At that time, the propeller was the only power setup in practical use for aircraft. It gave the craft high economy in takeoff and cruising and good maneuverability in the air. At the same time a light ramjet might offer the pilot greatly increased maximum flight speed when necessary. The suitability of the jet as an auxiliary motor was due also to the fact that it required no special fuel supply, which would be necessary, for example with liquid-propellant rocket engines, and it could be supplied the same gasoline as the main motor.

In August of 1939, the first models of the aviation ramjet--auxiliary to the DM-1 motor for use in ground tests--were designed and built. The diameter of these engines was 240 mm. Their test-stand were performed in September of 1939. The character and content of the tests are put forth in reports compiled from the results. Here is one:

"Report on the Tests of the air-breathing engine.

"On 17 September 1939, tests were performed with the air-breathing engine at the Planetarnaya station airfield.

"The tests were to prove the engine's reliability during extended operation and the engine was operated continuously up to 30 minutes.

"The tests were conducted on an engine with duralumin fairing and frames. Ignition was by two sparkplugs.

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"To test the safety of the plugs, two others were installed at other points in the engine.

"At 15 hr 26 min the engine was fired and operated without missing until 15 hr 57 min, when the fuel cock and air cock were closed.

"Thus, the engine operated 31 minutes. After the test, the engine's operation was checked. The engine appeared to be in completely good condition and the plugs were undamaged.

"Thus, the test established the complete reliability of the engine in continuous operation for one half hour.

"ORPI chief: Kol'tsov, Engine designer: Merkulov.

"Factory engineer: Maslov Factory flight mechanic: Karev"<sup>1</sup>

The successful tests of the DM-1 permitted proceeding to the preparation of engines for installation in aircraft. In September 1939, three models of the

<sup>1</sup> "A Concise Account of the Tests of the Air-Rocket Engine for Increasing Maximum Flight Speed," page 73. Scientific Archives of the Institute of History of Natural Sciences and Technology, USSR Academy of Sciences.

DM-2 auxiliary motors were prepared.

The auxiliary motor combustion chamber, unable to accomplish complete combustion, was aided by a special cooling system in which gasoline entering the engine was used as a coolant. The stability of gasoline combustion in the combustion chamber was achieved by a special structure, the so-called auxiliary rings, set within the combustor. They created a zone in the combustor where there were low airflow speeds and in these protected zones--the mixing chambers--there was ignition and stable combustion of a small amount of gasoline. The flame leaving the rings aided combustion distribution throughout the air mixture. To obtain ignition within the temperature limits  $-60^{\circ}$  to  $+60^{\circ}\text{C}$  and the possibilities for multiple starting in flight at various velocities, a special electrical ignition instrument was created and used in several flights.

The DM-2 engines were quite compact. Their length was 1500 mm, and maximum diameter was 400 mm, diameter of the nozzle exhaust section was 300 mm, engine weight was 12 kg without motors and 19 kg with motors.

To study the operation of ramjet engines before flight tests, a special wind tunnel AT-1 was constructed. (After improvement it was designated AT-2.) The maximum speed of the air flow in its working section was 75 m/sec. Tests of the auxiliary motors, first in the AT-1 and then in the AT-2, proved the safety of the engine operation, ignition, and the stability of the combustion and determined the engine's parameters. These tests were conducted throughout the period of flight tests of the auxiliary motors (DM) both with the aim of checking the structural improvements introduced during flight tests and for periodic control of the operation and condition of the engine itself. /43

Tests of two DM-2 models were initiated in October of 1939.

On 22 October 1939, official tests of the DM-2 took place in the wind tunnel. The results of these tests are given in the report, where it was stated:

"On 22 October 1939, tests of the air-rocket engine constructed by I. A. Merkulov were performed at the Frunze Central Airfield.

"The tests were witnessed by Central Committee Factory partorg (Party Organizer) G. V. Odinokov, factory director P. A. Voronik, and chief engineer P. V. Dement'yev. The tests took place in a special wind tunnel.

"The air-breathing engine operated on regular aviation gasoline with an ethyl liquid. Control of the engines was accomplished through handles on a control panel which controlled the supply of gasoline and buttons sending an electric flow to the engine sparkplugs.

"The amount of engine thrust was determined by single-component weight.

"During the tests, the engine was fired three times. The control components worked flawlessly. The engine showed complete reliability and safety from explosion.

"A speed of 120 km/hr was attained. At a given speed, the engine developed 10 kg of thrust, which corresponded to calculations."1

### Ramjet Engines in the I-15a Aircraft

After successful tests of the air-breathing engines in wind tunnels, they were installed for flight tests in the I-15a (I-152) No. 5942 designed by N. N. Polikarpov.

In the first tests, the aircraft in which they were installed was for all practical purposes a flying laboratory for testing the ramjet engine operation.

To shield the fuselage and tail structure from the possible harmful effects of engine combustion products, they were covered with sheet duraloy.

Flight tests of the I-15a with two ramjet engines set under the aircraft's 44 surfaces as auxiliary motors began December 1939. Tests of the first aircraft were by test pilot Petr Yermolayevich Loginov.

The first five flights were to check improvements on the machine. Then flights tested ignition in the air, and the engine's ignition. These first flights achieved reliable ignition and stable operation of the ramjet engine.

The official tests of the I-15a with ramjet engines were held on 25 January 1940. In accordance with his assignment, P. Ye. Loginov piloted the craft through several loops over the Frunze Central Airfield with the ramjet engines operating. During this flight, the pilot shut down and reignited the auxiliary motors several times. The engines' operation proved to be reliable, stable and safe for flight. Even when the pilot fed the auxiliary motors their maximum fuel load, during which the jet leaving the nozzle was longer than the fuselage, the craft banked well and the pilot controlled the craft easily, demonstrating its complete safety.

The flights by Loginov in December 1939 and January 1940 were the world's first flights of an aircraft equipped with air-breathing engines. It is interesting to note that the first flight of a foreign aircraft with air-breathing engine built by the Italian firm Caproni, which was widely publicized by the foreign press, occurred only in August of 1940, i.e., seven months after the flight of the Soviet I-15a aircraft with air-breathing engines.

Tests of the engines on the I-15a continued through February, March and May of 1940. These flights were to test the various structural improvements aimed at shortening ignition time, improving combustion and increasing the engines' effectiveness. Then flights were performed to measure the increase in speed due to the auxiliary motors. In these flights, in addition to Loginov, there were test pilots A. V. Davydov and N. A. Sopotsko. Flights on the I-15a aircraft with the DM-2 totalled 54. Of these, Loginov made 34, Davydov made 18, and Sopotsko made two flights. The craft's velocity with the ramjet operating 45

1  
Op. cit., page 74.

increased by an average 18-20 km/hr. The tests were at 320-340 km/hr. The auxiliary motors in these flights developed approximately 100 hp. A clearer indication of the flight results is given in the table.

/45

It must naturally be kept in mind that as engine weight increased, flight speed decreased somewhat, and the true increase in speed was less than the amounts indicated. However, in using an aircraft as a flying laboratory, the minor decrease in its velocity had no great significance, while in practical use of the ramjet, it has been proposed to substantially decrease drag through good fairing or even introducing additional motors in the craft's construction. This was being developed even during the flight tests.

#### RESULTS OF TESTS OF THE I-152-DM AIRCRAFT<sup>1</sup>

1940

Flight date	27 Feb	10 Mar	11 May	9 Jun	19 Jun	20 Jun
Altitude	2000	1250	2000	3200	1000	2000
Speed (km/hr)	311	301	304.5	317	302	313
Speed increase (km/hr)	21	17.0	22.0	19.5	18.0	18.0

The test pilots who performed the flights on the craft equipped with air-breathing engines voiced opinions of them, one of which we present here:

"Conclusion of pilot Loginov concerning the operation of the reaction engines designed by I. A. Merkulov.

"1. The engines give the I-152 aircraft an appreciable increase in speed.

"2. Control of the engines' operation is easy and simple (one control stick with switch).

"3. Engine operation at all speeds is stable and safe in terms of fireproofing when the craft's lower surface is shielded with a protective sheet of metal.

"4. The time required for starting the engine is somewhat long, 40-50 sec. This period should be shortened to 5-10 sec.

"5. The engines did not undergo complicated flight maneuvers.

"Test pilot Loginov.

"10 July 1940"

A special commission appointed by order of the Narkom (Peoples' Committee) compiled the following report: /46

"Report concerning tests of the I-15a aircraft with air-breathing motors.

"On the basis of flight-test results, the commission states that workers of

1

Op. cit., page 66.

the Aviakhim factory have created an air-breathing engine which operates in an aircraft and increases flight speed.

"The engine's safety, fire-resistance and durability have been proved by prolonged ground and flight tests.

"The tests have established that the air-breathing engines increase the craft's speed of 315 km/hr by 15 km/hr.

"The commission feels it worthy to continue tests on the high-speed engines, as they are the most effective air-breathing engines. At the same time, the Commission feels it necessary to continue work on the engines with the intention of increasing their efficiency, improving ignition, and accurately determining fuel required.

"Commission president Shumovskiy, chief military representative of the Frantsev. factory.

"Invention division chief Blayman.

"Designer Merkulov"<sup>1</sup>

#### The Ramjet Engine in the "Chayka" Aircraft

After the tests of the I-152-DM aircraft, tests of air-breathing engines were performed on the well-known "Chayka" I-153 aircraft designed by N. N. Polikarpov. Tests were performed on the I-153 craft No. 6034. Flight tests of the I-153 with DM-2 were begun in September 1940. They were performed by test pilots P. Ye. Loginov, A. I. Zhukov and A. V. Davydov. The average speed increase of the Chayka with operating DM was 30 km/hr. The table gives flight results.

#### RESULTS OF TESTS OF THE I-153-DM AIRCRAFT<sup>2</sup>

1940

Flight date	3 Sep	12 Sep	20 Sep
Altitude (m)	2000	2000	2000
Speed, (km/hr)	385	385	388
Speed increase (km/hr)	29	33	27

In August 1940, new DM-4 air-breathing engines were prepared which differed from the DM-2 by their larger dimensions. Construction of the DM-4 was an out-growth of the construction of the DM-2. /47

The first flight of the I-153 with DM-4 auxiliary motors took place on 3 October 1940. The aircraft rose to a height of 2000 meters and at an absolute speed of 388 km/hr, thanks to the ramjet engine, speed was increased by 42 km/hr, making it 430 km/hr. During later flights with DM-4 engines, the average increase

<sup>1</sup>

Op. cit., pages 3-4.

<sup>2</sup>

Op. cit., p. 69.

in speed was approximately 40 km/hr in comparison with flight without such engines. An increase from 389 km/hr to 440 km/hr, i.e., of 51 km/hr was obtained on 27 October 1940 in the I-153 with DM-4 engines at 2000 meters.

From the results of flight tests of the I-153 with DM, a report was prepared in which it was stated:

"In October 1940, the invention section of the factory performed flight tests of the I-153 aircraft with air-breathing engines designed by I. A. Merkulov. The engines were installed in the aircraft as auxiliary motors under the craft's lower surfaces and fastened to existing bomb girders. The two auxiliary motors weighed 60 kg.

"Fuel supply for the engines was from gasoline tanks on the craft which simultaneously fed the M-62 motor. The engines were controlled through a stick in the cabin.

"The I-153 was tested by Loginov at the Frunze Central Airfield. The program consisted of 20 flights providing a check of the craft's stability with the auxiliary motors, tests of their operation and determination of the increase in maximum speed.

"The flight tests completely established the effective operation of air-breathing engines and through their operation an increase in maximum flight speed.

"Tests showed these engines capable of operating on any type of aviation gasoline regardless of the proportion of ethyl.

"The engine's durability has been proved in prolonged ground and flight tests. Flight tests have established that firing the engines on the I-153 flying at an altitude of 2000 m increases its top speed from 389 km/hr to 440 km/hr, i.e., by 51 km/hr."<sup>1</sup>

Flight test results received a positive evaluation in the Narkom aviation industry Order No. 391 of 16 December 1940.

The tests permitted both basic debugging of the engines and further R and D <sup>/48</sup> work in improving them. As the tests clearly showed, these problems included studying combustion in the ramjet combustor and improving it to attain full combustion, improving the ignition system and improving construction of the ramjet with respect to its further simplification, as well as equipping the engines with control/measurement equipment and automation.

"Tests of aircraft with both DM-2 and DM-4 air-breathing engines totalled 74 flights with no accidents.

Work in planning and flight tests of the ramjet on aircraft designed by N. N. Polikarpov was initiated in the special construction section under the direction of A. Ya. Shcherbakov and continued in the invention section directed

<sup>1</sup>

Op. cit., pp. 5-6.

by V. V. Kol'tsov and P. M. Blayman of the Aviakhim factory. It was accomplished by the design group, which included designers I. A. Merkulov, A. P. Masolov, A. A. Mel'nikov and B. A. Nikolayveskiy, engineers A. A. Gonsovskaya and Z. V. Tolstikova, aviation mechanics I. A. Charnyy, P. V. Karev and A. N. Il'in and G. P. Rybokov.

Simultaneously with the ramjet engine tests described here, our group performed successful work in high-altitude stratospheric flights as well.

By the end of 1940, these works accomplished the creation of several air-tight cabins in which flights above 12 km were accomplished.

Such a cabin underwent government testing in the I-153 at the Air Force Research Institute and was recommended for installation in several fighter aircraft.

This success in creating air-tight cabins, high-altitude flights on gliders mentioned in the Soviet and foreign press and successful tests of ramjet engines served as a basis for solving the important question raised by the Central Committee of the All-Union Communist (Bolshevik) Party and the USSR Soviet of Peoples' Commissars concerning the organization of a test factory at which work might be continued in attaining high-speed altitude flights.

The factory began organizing in the second quarter of 1941 in unsuitable quarters and just as it began to produce, World War Two began and curtailed the continuance of work in this field on the scope and scale intended.

/49

EXPERIMENTAL PREPARATION FOR FLIGHT TESTS OF THE  
RAMJET ENGINE IN AN AIRCRAFT DESIGNED BY  
A. S. YAKOVLEV IN 1942-1944

K. A. Putilov

In all our affairs, the most impartially strict judge is time. After a quarter century has passed and we glance back, we realize that much of what we scientists and technicians have done was incorrect or immaterial and suddenly little appears historically important. Today we recall with great interest one of these useful items--the creation of the theory of air-breathing engines and the first researches and investigations with ramjet engines to support this theory experimentally. /50

Before the War, in 1939 and 1940, and during the War, we in the USSR had been studying ramjet engines in several laboratories and groups directed by V. S. Zuyev, Ye. S. Shchetinkov, M. M. Bondaryuk and I. A. Merkulov.

I can speak only of the work in which I took some part--that of the special design office directed by Igor Alekseyevich Merkulov.

What challenge faced us in those years?

There was the theory of the air-breathing engine put forth by Boris Sergeyevich Stechkin and developed by his students and successors, among whom Moris Rua is well remembered. There were the results of the first experimental studies of the ramjet engine performed in 1933-1935 by Yu. A. Pobedonostsev in GIRD and RNII, and in 1935 by Rene Leduc in France. There were the highly valuable results of that era's most complete laboratory studies of the ramjet engine combustion processes by V. S. Zuyev in 1937-1940 and the flight-test results of the ramjet engine in rockets and aircraft as well as in the TsAGI (Zhukovskiy Central Aerohydrodynamic Institute) T-104 wind tunnel accomplished by I. A. Merkulov in 1939-1941. However, these data alone could not offer complete experimental proof of the theory and calculation methods of the ramjet engines for designing high-power ramjet engines. /51

Therefore, the most immediate problem was to design satisfactorily performing models of the ramjet engine and test them initially on the ground, but under conditions more-or-less approximating those of flight, and then necessarily flight-test them.

Such firing tests of aircraft ramjet engines, some of the world's first in their thoroughness, were prepared and performed by a special design office and the Ordzhonikidze Aviation Institute in Moscow.

It must be stated that in those years few were willing to share the enthusiasm in rocket technology, because this field then appeared exotic and diverging from the pressing needs of aviation. We were fortunate that the Director of MAI (Sergo Ordzhonikidze Moscow Order-of-Lenin Aviation Institute) then was Aleksandr Ivanovich Mikhaylov. At his own risk, to aid the SKB (Special Design Office),

he established the Special Experimental Investigation Group (SEIG) and the theme "Further Improvement and Testing of Special Types of Auxiliary Motors."

With the concurrence of A. I. Mikhaylov and his assistant Professor Nikolay Viktorovich Inozemtsev, we succeeded in surmounting the various and often complex obstacles arising from the difficulties of the war years.

In 1942, the engineers and technicians of the SKB and their co-workers from SEIG MAI designed a steel wind tunnel with a length of 17 m and a working section diameter of 1 m. The speed of the airflow in the tunnel's working section was around 50 m/sec. The tunnel was equipped with measurement apparatus for simultaneous measurements of twenty-two parameters: temperature, speed and pressure at various points of the ramjet.

Due to the war, Merkulov set up the design models of the ramjet far from Moscow, and they were flown to Moscow for tests and further improvements.

V. I. Bukharin, N. I. Zaikin, D. N. Chekletov, O. S. Oganessov and others took part in the structural development of the engines. The engineer B. A. Nikolayevskiy planned the engine's installation in the aircraft, the fuel supply system, electrical supply and control. In-operation blowdown in the tunnel was conducted by B. A. Nikolayevskiy, B. R. Pastukhovskiy, I. A. Charnyy and Ye. A. Asadchikov. In Moscow, the spirit of the operations, the organizer of tests and initiator of various improvements was the indefatigable inventor, the partorg (party organizer) of the MAI department of Physics, Boris Rafailovich Pastukhovskiy. I have never met a more enthusiastic supporter of jet technology. Alas, a few years after this period described, nervous overstrain due to such work ended the life of this remarkable man. We will always revere his memory. 52

Many unforeseen difficulties arose during operational tests of the ramjet engine. Department members P. V. Matorin and S. A. Lapushkin aided in solving some of them.

What had to be studied first in ground tests? First, the conditions for sufficiently complete fuel combustion and pressure change throughout the gas-air duct of the engine, i.e. those processes which affect the speed of gas flow from the nozzle. It was of course necessary to test and develop the ignition reliability, combustion stability and the fire-resistance of all of the engine's structural components.

To arrive at a solution to these questions, flow velocities were measured at the intake, at the exhaust and in the working section. Static pressure was measured along the engine axis in front of the diffuser, at several points in the diffuser and in the combustor. Air temperature after compression in the diffuser was measured, as were the temperature in the combustor and in the exhaust section of the nozzle along the axis and near the walls. These data permitted calculation of all the processes with sufficient accuracy. Flight tests on aircraft designed by N. N. Polikarpov showed both the positive features of these engines: safety, durability, ability to operate on any type of aviation gasoline, stability of the combustion process, and fair reliability of the ignition system, as well as their faults, chief of which was incomplete combustion.

Therefore, immediately after completion of the flight tests, in 1941 tests of the DM-4 engine were run in the TsAGI T-104 wind tunnel and revealed the causes of low combustion. Thus, several changes were introduced into the new DM-4s engines to be used in tests on an aircraft designed by A. S. Yakovleva (the YaK 7) to increase the completion of combustion and decrease pressure losses. In addition, the DM-4s incorporated detachable diffusers and nozzles of various dimensions, for selection of optimal geometrical parameters for the engine during tests. In addition to the basic version of the diffuser, one was designed with an injector in which vaporous gasoline served as the fuel. The protective rings installed in the combustion chamber also had several designs.

Because tests in the T-104 tunnel showed that the peripheral fuel supply does not yield a uniform gasoline mixture, the new engines had annular burners throughout the section of the combustion chamber. These had various structures for flame stabilization. Ignition in the auxiliary motors was started by the ZPz-DM-5 device powered by a 12-A-30 battery. The circuit feeding power to the ignition device was tied in to the AZ-DM-1 automatic device, which automatically broke the circuit after the engines started. If the engines were to die, as a result of a prolonged lapse in fuel supply for example, the AZ-DM-1 would start the flow to the combustor. The DM-4s had a diameter of 500 mm and a length of 2430 mm. /53

The three removable diffusers had intake sections of 230, 280 and 330 mm. The removable nozzles had intake diameters of 300, 340 and 360 mm.

Tests in the AT-2 tunnel began in mid-August of 1942. The first step was to test the engines in operation after their production, adjust and check the whole complex in operation and debug especially the fuel flow in the welded seams and the connecting pipes and gas flow at points where the removable attachments met the body. Much attention was paid to tests and corrections of the ignition system in the auxiliary motors. At the same time, the measurement device reinstalled in the tunnel was tested. The nature of the first tests is clearly illustrated in reports from that time, one of which we present here:

#### REPORT NO. 1

This report has been prepared by the Commission consisting of: Chief of test Station I. A. Charnyy, chief test station engineer Ye. A. Asadchikov and engineer B. A. Nikolayevskiy to state that DM-4s engine No. 14 was installed in the AT-2 wind tunnel on 17 August 1942 for testing ignition and combustion.

After the first fuel combustion, the engine was shut down and examined. Inflows of fuel under the external ring were observed.

At second starting, with the external ring secured, flame was noticed under the engine's body cone, as a result of which the engine was shut down.

A flow of fuel was established in the space under the body cone caused by a crack in the welded seams of the body.

Further tests cannot take place without eliminating this defect.

Ignition of fuel in the engines in the first and second cases occurred normally.<sup>1</sup>

/54

Our investigation group naturally had to eliminate all these bugs with great effort and at the expense of a significant amount of time.

On 22 August, the second DM-4s engine, No. 15, was installed in the wind tunnel. Ignition failed in the first four attempts. After adjustment of the electric ignition device, the engine did not ignite for three tests, and this was found to be caused by obstruction in the flow meter through which the fuel passed. On 29 August, the test of engine No. 15 continued. This time the engine ignited normally. Three tongues of flame were clearly visible whose centers were like connecting pipes guiding the gasoline to the burner. With an airflow speed of  $\sqrt{tr} = 47$  m/sec in the working section and a fuel supply of  $120 \text{ cm}^3/\text{sec}$ , the jet was 1 to 1.5 m in length. The engine operated 3 minutes with fuel supply varying from 50 to  $150 \text{ cm}^3/\text{sec}$ . Five tests were conducted on 31 August. In the first, the engine did not start, but the four subsequent tests were normal.

Thus, day by day there were further improvement and testing of the DM-4s ramjet engines at SEIG MAI.

The measurements and visual observations conducted in the first tests permitted determination of the characteristics of the flame in the combustion chamber with various burners and introducing improvements in the distribution of the force pumps throughout the burner tubes.

All initial tests were conducted on two DM-4s engines Nos. 14 and 15, so as to establish the necessary corrections and definitely select the armature and force pump distribution system variations to introduce into the types of DM-4s motors Nos. 16 and 17 intended for flight tests, while avoiding intermediate alterations in the flight models.

Upon completion of the first stage of the tests, the operational characteristics of the jet engines were studied.

As a result of carrying out all the tests in the wind tunnel and making further improvements, the safety of the DM-4s engine was ensured, the fire-resistance of all components was proved and operational reliability in the engine was /55 established. Thus, through the cooperative work of the Moscow Aviation Institute and the Special Design Office, the DM-4s ramjet engines were prepared for flight tests on the YaK-7B aircraft.

At the same time, studies of these engines showed that the gas temperature in the combustion chamber and gas velocity were somewhat lower than calculation. Therefore, in the report on the test-stand studies one conclusion stated:

"Along with the tests of the DM-4s motor on aircraft, it is most necessary  
1

Scientific Archives of the Institute of History of Natural Sciences and Technology of the USSR.

to perform further work in improving it, especially in achieving complete combustion, since comparison of calculated and experimental temperatures shows that full combustion has still not been achieved."<sup>1</sup>

As a result of tests of the engines, work on equipping the YaK-7B was started. The following report indicates clearly the character of this work:

Report of Work Completed on the YaK-7B Aircraft No. 820803 with No. 105  
PF Motor No. 45-32

23 February 1944. We the undersigned: chief factory engineer V. A. Romadin, Chief of section No. 6 N. S. Laptev for chief of factory quality control section G. A. Tsesarskiy and chief engineer B. A. Nikolayevskiy have prepared this report that the following operations have been performed on the aircraft at NKAP factory No. 482.

1. Suspension of auxiliary engines.
2. Connection of gasoline supply lines to the engines.
3. Installation of fuel system units (auxiliary pumps, stopcocks).
4. Arrangement of valve control.
5. Installation of electric ignition of the engines.
6. Installation of engine control instruments.
7. Equipping rear cockpit for observer.
8. Improvement of landing gear and pneumatic system.
9. Calibration of instruments.
10. Debugging according to the engineering control list.
11. Painting aircraft.

These operations were conducted in compliance with plans drawn up by the design office (chief: I. A. Verkulov) and according to instructions of chief aircraft engineer B. A. Nikolayevskiy.

All these operations were accepted by the factory quality control dept.<sup>2</sup>

In 1944, the YaK-7B aircraft underwent flight testing of its DM-4s engines 56 to further improve their ignition, combustion, stability and synchronized engine operation under one of the most experienced test pilots, Sergey Nikolayevich Aneshchenko. According to the report, the following results were achieved.

The DM-4s engines on the YaK-7 were fired in flight at top speed at altitudes up to 5000 m. The design of the DM-4s permitted in-flight shutdown and reignition. Operation was simple. In-flight engine control presented the fliers no difficulties. The engines operated on aviation gasoline from the same tanks as the main engine. Equal performance was obtained from both engines.

<sup>1</sup>

"Preliminary report on the tests of the DM-4s auxiliary engines in the AT-2 wind tunnel" (Predvaritel'nyy otchet ob ispytaniyakh dopolnitel'nykh motorov DM-4s v trube AT-2) 1943, p. 12.

<sup>2</sup>

Scientific Archives of the Institute of History of Natural Science and Technology of the USSR Academy of Sciences.

After this stage of flight tests, it was proposed to collect the detailed thrust characteristics for various parameters of engine design and its future improvement. Therefore, firing the engine and other problems of the first stage of the tests were carried out with arbitrary hardware and engine parameters and not those which appeared optimum on the basis of theoretical calculations and wind-tunnel tests. However, after the first stage was completed, flight tests were stopped due to a heavy discharge of fuel during operation of the engine. Fortunately, during one of the first-stage flights, i.e., during adjustment of the engines, a significant increase in the craft's speed was obtained through the operation of the air-breathing engines. This flight took place at 2340 m in altitude, where the maximum level speed of the test model of the YaK-7B without the DM-4s working was 460 km/hr. With the engine operating, the maximum speed increased by 53 km/hr, i.e., to 513 km/hr. The top speed of the YaK-7B without the auxiliary engines at a given altitude was 494 km/hr. Thus, the actual increase in speed was 19 km/hr. However, in evaluating this result, we must consider that both engines were suspended from the wings without fairing and that this suspension constitutes significant drag for both the engine and wing.

These results now seem understandably quite modest, but we cannot forget how important they were for that time.

Each research engineer and physicist knows how often new theories for invented machines prove incorrect upon experimental testing. A quarter century ago, everyone feared that this might be true of the ramjet engine theory. /57

The main result of test-stand and flight testing was that they proved the correctness of the theory and calculation methods put forth earlier, and thus showed that detailed structural development of the engine and the deepening of theory which was necessary to do so was a matter of government importance.

The legacy of B. S. Stechkin, Yu. A. Pobedonostsev and I. A. Merkulov was passed on to many strong scientific and engineering institutions. One of these grew out of the group headed by Mikhail Makarovich Bondaryuk, created in the first years of the war. The guiding spirit, along with M. M. Bondaryuk, was the remarkable scientist Sergey Mikhaylovich Il'yashenko. He presented brilliant undergraduate and graduate dissertations on deepening ramjet theory. I consider his monograph, prepared with M. M. Bondaryuk, to be the best in this field.

In those years, the ramjet's extreme fuel consumption frightened many scientists. Now, however, all seem to recognize that at flight speeds twice or more that of sound the ramjet is the most economical of engines. Its efficiency may substantially exceed 40 percent. This and the absence of loaded rotation parts will aid its prevalence in the future.

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# HISTORY OF AVIATION AND COSMONAUTICS, VOL. IV

(Editorial Board) N.D. Anoshchenko, A.M. Izakson,  
I.A. Merkulov, S.A. Sokolova, V.N. Sokol'skiy,  
and V.B. Shavrov

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## IN MEMORY OF SERGEY PAVLOVICH KOROLEV

B.V. and M.K.

On January 14, 1966, in Moscow, died an outstanding Soviet designer and scientist, member of the Presidium of Academy of Sciences SSSR, Communist, Academician Sergey Pavlovich Korolev, who worked in the area of rocket and space technology. With his death Soviet and world science has lost a leading activist whose name is inseparably connected with the start of a new era of man's mastering of space. /3\*

Sergey Pavlovich was born on December 30 1906 at Zhitomir, in the family of a teacher. Having enrolled in the Kiev Polytechnic Institute after receiving a secondary education, he transferred in 1926 to the third course at the Moscow Technical School of Higher Learning, and completed Department of Aeronautical Engineering in 1929. He combined his studies at the higher institution of learning with work in the aviation industry. /4

Having become enthused in problems of gliding and light-engine aviation, he, with his characteristic energy, completed pilot training in 1930 and simultaneously was engaged in designing gliders. In 1929, at the Sixth All-Union Glider Competition he was one of the designers of the "Koktebel" glider. In 1930 he designed and built the "Krasnaya Zvezda" glider on which pilot V.A. Stepanchenek was the first in the history of aviation to perform acrobatic maneuvers. Only a sudden illness prevented Sergey Pavlovich himself from completing these flights, outstanding for that time. In 1930 he made his first flight on the light-engine aircraft SK-4 which he designed. In 1935 Sergey Pavlovich participated in the second All-Union meeting of glider pilots as the pilot and designer of the two-place SK-9 glider, on which a liquid-fuel rocket engine was subsequently installed.

Sergey Pavlovich began his activity in the area of rocket engineering in 1930. Having become familiar with Konstantin Eduardovich Tsiolkovskiy and his works, Sergey Pavlovich devoted his entire life to accomplishing the bold dream of mankind--space exploration. The Group for the Study of Jet Propulsion (GSJP), founded with his participation, became the center in Moscow around which during the 1920s gathered rocket engineering enthusiasts. From that time until the end of his life he devoted all his efforts to development of Soviet rocket and space technology.

Sergey Pavlovich, heading the GSJP team since 1932, worked hard and fruitfully on the design of the first experimental engine and rockets and solved a number of theoretical problems. In 1934 he gave a report on the flight of jet craft in the stratosphere at the All-Union Conference for the Study of the Stratosphere at Leningrad.

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\*Numbers in the margin indicate pagination in the foreign text.

After organization of the Jet Research Institute at the end of 1933, S.P. Korolev accomplished considerable organizational, research, and design work at this Institute, directing his creative efforts to the development of long-range, winged guided missiles and rocket aircraft. /5

Considering that one of the main purposes in the development of rocket engineering was to create craft capable of lifting man, he personally flew, while still in the GSJP, the BICh-II tailless glider designed by B.I. Cheranovskiy on which a rocket engine was subsequently mounted. The project of mounting such a motor on a glider could not be accomplished at that time, but in 1940 pilot V.P. Fedorov flew the abovementioned SK-9 glider with a liquid-fuel rocket engine mounted on it. Thus, the first manned flight on an aircraft with a liquid fuel rocket engine, still within the atmosphere, was accomplished on an aircraft designed by S.P. Korolev.

During the second World War S.P. Korolev worked on the installation of liquid-fuel jet boosters on fighters and dive bombers and personally participated in test flights.

Sergey Pavlovich later worked intensely on the theory and practice of rocket engineering, from time to time combining his work with teaching at institutes of higher learning.

S.P. Korolev was the designer of space rocket systems on which the world's first launchings of artificial earth satellites were accomplished, including the launching of the first satellite on October 4 1957, the delivery of the Soviet emblem to the moon, and the fly-by and photographing of the far side of the moon, which in essence meant the creation of new, experimental astronomy together with the long-existent observational astronomy.

Spaceships were created under the supervision of S.P. Korolev on which equipment was worked out for manned flight into space and for the return of the spacecraft to earth, as well as the piloted space ships "Vostok" and "Voskhod" on which man, for the first time in history, completed a flight into space and the first space walk.

Sergy Pavlovich taught numerous scientists and engineers who are presently working at many research institutes and design departments in the area of rocket and space technology. He had many pupils and followers.

Inexhaustible energy, talent as a scientific researcher, magnificent engineering intuition, great creative boldness in solving the most complex scientific and technical problems were combined in S.P. Korolev with brilliant organizational abilities and high personal qualities. /6

S.P. Korolev was highly respected and won the esteem of all who worked with him. In 1953 he was elected a corresponding member of the Academy of Sciences of the USSR, and in 1958 an Academician.

The fruitful activity of Sergey Pavlovich Korolev earned the gratitude of the Soviet people and was marked by high government awards. For outstanding service to the Motherland he was twice awarded the title of Hero of Socialist

Labor, winner of the Lenin Prize, and was awarded orders and medals of the Soviet Union.

S.V. Keldysh, president of the Academy of Sciences of the USSR, stated that the name of S.P. Korolev "will always be related with one of the most outstanding victories of science and technology of all times--the opening of the era of man's conquest of space," and that Academician S. P. Korolev "belongs to those remarkable scientists of our country who have made an indelible contribution to the development of world science and culture."

We cannot help but be sorry that death has terminated his activity and that he will not be able to enjoy the latest achievements of astronautics to which he devoted his entire efforts.

The memory of Academician Sergey Pavlovich Korolev, a true son of the Communist Party, who selflessly served his Motherland, will always be preserved in our country.



PRACTICAL SIGNIFICANCE OF THE SCIENTIFIC AND TECHNICAL PROPOSALS  
OF K.E. TSIOLKOVSKIY IN THE FIELD OF ROCKET ENGINEERING\*

S. P. Korolev

ABSTRACT. A brief history of the contributions made by K. E. Tsiolkovskiy, father of Russian rocketry. The author reviews the contributions of Tsiolkovskiy to present day rocket technology.

In our day rocket engineering is one of the leading areas of modern science and technology. The time has long passed since the remote concepts of "fiery arrows" of ancient China and India, of the rocket missiles of the Englishman Congrew and Russian general K.I. Konstantinov were associated with rockets. /7

During the years of the second World War the mortar units of the Soviet Army armed with solid-fuel rocket projectiles often, while protecting our Motherland, subjected the horde of Fascist bandits to annihilating destruction.

During the post-war years aircraft with jet engines of different types became increasingly more widespread. The jet express TU-104 flies the airlines. New, remarkable models of high-speed jet aircraft have been created; significant flying speeds and altitudes have been achieved by aircraft; the so-called "sound barrier" has been left far behind. Two types of aircraft, and in particular, military aircraft, are being developed, generally with jet engines.

In high-speed aviation a transitional critical period, so to speak, has presently arisen--from aircraft to rocket. Soviet pilots for the first time in history have flown aircraft with liquid-fuel jet engines.

Extensive investigations of the upper layers of the atmosphere and space above the atmosphere are being carried out by the Academy of Sciences of the USSR in vertical launchings of high-altitude rockets. Complex research equipment and experimental animals are being carried aloft in rockets and returned to earth. Soviet rockets are making flights at very great altitudes above the earth's surface which no one has yet reached. /8

The Soviet Union is successfully testing super long-range, intercontinental, multistage, ballistic rockets. The results obtained show that it is possible to launch rockets to any region of the earth.

During the period of the now approaching International Geophysical Year dozens of rockets will be launched to conduct scientific investigations according to diverse programs for different altitudes and in different regions of the \*A report given by S.P. Korolev on September 17 1957 at the ceremonial assembly meeting of the Academy of Sciences of the USSR devoted to the One-Hundredth Anniversary of the birth of K. E. Tsiolkovskiy. An abridged verbatim report is published.

Soviet Union, including regions of the Far North and Soviet expeditions to the Antarctic.

In the near future the first test launchings of artificial earth satellites will be carried out in the USSR and USA.

Soviet scientists are working on many new problems of rocket engineering, for example: on the problem of sending rockets to the moon and lunar fly-by, on the problem of manned flight in a rocket, on problems of deep penetration and investigation of space.

This is far from a complete review of the outstanding events in the area of scientific and technological progress associated with the development and achievements of rocket engineering in the Soviet Union during the past 15-20 years.

The remarkable predictions of Konstantin Eduardovich Tsiolkovskiy concerning rocket flight and flights into interplanetary space which he expressed more than 60 years ago, are coming true.

Konstantin Eduardovich wrote with enormous force and conviction in one of his letters: "Man will not remain eternally on earth, but in the pursuit for light and space, he will at first timidly penetrate beyond the limits of the atmosphere and then conquer all solar space."\*

The most remarkable, bold, and original creations of Tsiolkovskiy's creative mind were his ideas and works in the area of rocket engineering. Here he had no predecessors and far outstripped scientists of all countries and was far ahead of his time.

Konstantin Eduardovich Tsiolkovskiy was a scientist and experimenter, self-educated, who by his untiring labors independently raised science and scientific foresight to extraordinary heights. He was an inventor who affirmed the priority of our Motherland by a number of outstanding inventions and technical proposals in the area of gliding, aviation, and especially in the field of rocket engineering, which now has such topical importance. /9

He was a scientist and researcher who boldly paved the way to the new, still uninvisioned in science, and as a true scientist he brilliantly, scientifically substantiated his discoveries. And, finally, he was an ardent patriot of the Soviet Motherland, an indefatigable worker and eager enthusiast of science, to which he wholly devoted and gave his life.

In 1873 the 16-year-old Tsiolkovskiy went to Moscow. During his Moscow period the general direction of future endeavors, technical ideas and works which Tsiolkovskiy subsequently followed during his entire life, was mapped out.

This pertains to his thoughts as to whether various properties of matter could be used for realizing some type of moving apparatus. Thoughts of gravity and means of combatting gravity occupied Tsiolkovskiy.

\*Letter of K. E. Tsiolkovskiy to B. N. Vorob'yev dated August 12 1911 (Archive of the USSR Academy of Sciences).

Thus, even then, vague ideas about the possibility of manned flight beyond the limits of the earth's gravity or, as he himself subsequently stated, "fascinating dreams," took form in Tsiolkovskiy's conscience. The first projects proved to be failures, the first attempts to invent ended unsuccessfully, but this did not cool the energy of Tsiolkovskiy.

Many years of persistent work passed, agonizing doubts in complete solitude, without support, without any sympathy, and often with outright disapproval and even mockery addressed to the queer, half-deaf school pupil and "mad inventor," which Tsiolkovskiy was considered by the local officials and bureaucratic top echelon of the engineering and technical strata of tsarist Russia.

In 1883, in his work "Free Space," which was a unique scientific diary, Tsiolkovskiy examines the occurrence of the simplest phenomena of mechanical motion in space without the effect of gravity and drag.

Examining methods of imparting motion to a body in free space, Tsiolkovskiy arrived at his most basic and important fundamental conclusion, that it is simplest to impart motion to a fixed body (or to change motion) by thrusting a mass backward, i.e., by the reaction of particles thrust from a given body. This is what Tsiolkovskiy writes in his work "Free Space":

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"28 March 1883. Morning.

...let us assume that we have a barrel filled with a strongly compressed gas. If one of its thinnest stopcocks is turned, then the gas will rush from the barrel in a continuous stream, whereby the pressure of the gas repelling its particles into space will also continuously repel the barrel.

"The results of this will be a continuous change of motion of the barrel.... By means of a sufficient number of stopcocks (6) it is possible to control the escape of gas so that motion of the barrel or the hollow sphere will depend completely on the desires of the one controlling the stopcocks, i.e., the barrel can describe some desired curve and obey some desired law of velocities....

"The motion of the barrel can be changed only until all gas has escaped from it.

"...In general, uniform motion over a curve or rectilinear, nonuniform motion is associated in free space with continuous loss of matter (support)."

Thus, the principle of jet propulsion was developed by Tsiolkovskiy at the very beginning of his independent scientific activity.

In the article "Free Space" there are no quantitative results, or findings are constructed on qualitative conclusions from the law of conservation of momentum for closed mechanical systems, but the expediency of using the reaction of an escaping stream for motion in free space is formulated distinctly and clearly.

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K.E. Tsiolkovskiy: Collective works, Vol. II. Moscow, Izd-vo AN SSSR, p. 52, 1954.

In 1896 Tsiolkovskiy finally arrived at the conclusion that the only technical means for flight into outer space is the rocket. In 1903 Tsiolkovskiy published his work "Investigation of World Space by Jet Apparatus." This classical work is rightfully considered the world's first scientific work devoted to problems of the theory of motion and to a variety of important fundamental technical proposals in the area of rocket engineering. /11

Tsiolkovskiy saw the vast future in the development of rocket engineering, but simultaneously he clearly understood what difficulties had to be faced. He wrote: "...as a researcher of the atmosphere I propose a jet apparatus, i.e., a kind of rocket, but one that is grandiose and specially constructed. The idea is not new, but the calculations pertaining to it give such remarkable results that it would be impermissible to fail to mention them.

"This work of mine far from examines all aspects of the matter and does not solve it at all from the practical point of view relative to feasibility; but in the far future the prospects, so alluring and important that even now one can dream about them, are already apparent through the haze."\*

In supplements to this work published in 1911-1912 and 1914 and later, and in numerous works, articles, projects, and manuscripts on which Tsiolkovskiy worked until the last days of his life, he examined a wide range of problems of a theoretical, research, and design nature, as well as numerous problems having applied technical, design, and technological values.

In developing theory and in investigating laws of rocket motion Tsiolkovskiy held to a strict sequence in his works. At first he solved the simplest problem on the assumption that during rocket flight there was no force of gravity of drag. This problem is now called Tsiolkovskiy's first problem.

He introduced the hypothesis of the constancy of the relative rate of rejection of particles for certain substances. This hypothesis is called Tsiolkovskiy's hypothesis.

He wrote the basic equation of motion of a rocket in a medium without the effect of external forces, known as Tsiolkovskiy's formula. In this equation the ratio of fuel weight to the end weight of the empty rocket is called the Tsiolkovskiy number. He wrote a number of theorems bearing his name.

When calculating rocket motion a complicating factor is the appreciable change in mass of the rocket apparatus during travel. This condition does not permit using formulas of classical mechanics for calculation. An unquestionable service of Tsiolkovskiy in developing rocket theory was the elaboration of a number of applied problems of a new section of classical mechanics--mechanics of bodies of variable mass--which he accomplished independently of other similar works. /12

Having examined rocket motion in a medium without the effect of external forces, Tsiolkovskiy thoroughly investigated the effect of the forces of gravity and drag on rocket flight. It is necessary to point out a characteristic K.E. Tsiolkovskiy: Collected works, Vol. II, p. 73.

feature of Konstantin Eduardovich--he was a persistent battler for overcoming the forces of gravity, he considered the force of earth's gravity to be, so to speak, a chain binding mankind to the surface of our planet. He called the range of action of gravitational forces the armor of gravitation.

In almost all his works Tsiolkovskiy inevitably returned to the problem of combatting gravity. He conducted investigations and calculations to determine fuel reserves needed to overcome the armor of gravitation and to find those optimal conditions under which energy expenditure during takeoff of a rocket would be minimal.

An appreciable place in his investigations is occupied by the problem of the effect of drag on rocket motion, fuel supplies, and the most advantageous flight conditions necessary to penetrate the earth's atmosphere. Tsiolkovskiy called the range of action of drag the armor of the atmosphere.

In his theoretical works Tsiolkovskiy arrived at a variety of major conclusions which even today are widely employed in rocket engineering.

Furthermore, as practical works developed and rocket engineering improved, increasingly more conclusions and hypotheses of Konstantin Eduardovich, which he expressed long ago, were verified.

His investigations showed that velocity, and, hence, range of rocket flight increase with an increase of the relative supply of explosives (fuel) on board the rocket. By supplying them in different quantities, it is possible to achieve any terminal velocity and any range.

Velocity at the end of combustion (at the end of the powered flight of the rocket) proves to be more, the higher the relative speed of the rejected particles. The speed of the rocket at the end of the powered section of the trajectory also increases with an increase in the ratio of initial rocket weight to its weight at the end of combustion.

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A quite important practical conclusion follows from the Tsiolkovskiy formula: higher rocket speeds can be accomplished more effectively by increasing the relative speeds of the ejected particles, i.e., by improving the power plant, then by increasing the relative fuel supply on board the rocket, i.e., by improving its design.

Tsiolkovskiy was the first to determine the degree of utilization or efficiency of a rocket, having indicated the advantage of using rocket engines only at high speeds. Examining problems of using liquid-fuel rockets for flight in the dense layers of the atmosphere, he arrived at negative conclusions.

Tsiolkovskiy performed investigations and calculations pertaining to rocket launch and selection of optimal launch conditions and examined a vertical launch, inclined launch, and launch from a prescribed initial height.

He performed the first calculations to select the best angle of climb with consideration of losses to overcome forces of gravity and drag during flight in

a medium having a variable density, change of the altitude characteristics of an engine, and many other calculations and investigations.

A special feature of the creative method of Tsiolkovskiy lay in the thorough, practical elaboration of each problem examined. Under conditions of tsarist Russia Tsiolkovskiy had limited opportunity for experimenting, he did not have at his disposal either equipped laboratories, or experimental stands, or design departments and factories. He did not have assistants, and extreme independence and self-dependence were characteristic of him.

But he did not simply theorize; with exceptional insight and depth he supplemented all his, sometimes highly unusual, theoretical conclusions with such earnest and detailed practical considerations that a vast number of them found use and are widely employed even today in all countries of the world engaged in rocket engineering.

Here are some of the most interesting of these problems. Konstantin Eduardovich thoroughly investigated rocket energetics, selection of fuel for engines, and their construction. He formulated the basic requirements for fuels and hypotheses on the selection of fuel in terms of the highest energy producers per unit mass, highest possible density of the fuel, and in terms of a number of other characteristics. Tsiolkovskiy settled his selection on liquid fuel with the use of liquid oxygen, liquid hydrogen, and petroleum and its derivatives.

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He proposed a special detonation tube in the form of an expanding cone and combustion chamber to which the fuel was delivered by pumps, and proposed automatic control of combustion processes in the motor so as to regulate its operating conditions with the specific conditions of rocket travel over a trajectory.

In order to create the most favorable conditions for fuel combustion, he had in mind the establishment of a grid with oblique aperture at the inlet to the detonation tube. Tsiolkovskiy suggested that it was best to determine the number, size, and slope of the apertures in the grids by experiment.

Problems of cooling the blast tube where extremely high temperatures should develop brought up special dangers. This problem was to be solved by cooling the tube by the fuel components or by some liquid metal situated in a special jacket.

Tsiolkovskiy very thoroughly investigated ways of protecting the blast tube against the effect of high temperatures, examined various materials for manufacturing the tube, and proposed to protect it by refractory or heat-resistant materials.

He determined the powers required for pump operation at different combustion pressures and supply systems, and also investigated processes of delivery, atomization, ignition, and combustion of fuel.

In Tsiolkovskiy's works we can find mention of the probable use of atomic

energy, solar energy, and energy of cosmic radiation to impart motion to the rocket.

However, he qualified his calculations by stating that they did not produce the desired results and that, although all discoveries are possible and dreams can unexpectedly be fulfilled, in his works he wants to stand as much as possible on practical soil.

Tsiolkovskiy expressed the interesting thought of controlling rocket flight by using the energy of a stream of escaping gases. He proposed a device for turning the end of a branch pipe of the blast tube, or a gas rudder in the form of plates installed in the gas stream. /15

Tsiolkovskiy foresaw that manual control of a rocket flight would be not only difficult but practically impossible. Therefore, automatic equipment and gyroscope instruments ought to be installed on board a rocket to generate the necessary control signals. Orientation in space during rocket flight could be accomplished automatically by a servo system using magnetic properties or fixed on the sun or on some star.

At the same time he proposed air rudders, elevators, and something not unlike ailerons designed for operating when the rocket flies in sufficiently dense layers of the atmosphere.

Tsiolkovskiy elaborated a variety of interesting problems related with rocket design, selection of its shape, internal components, arrangement of mass within the rocket, and possible systems of various power and hermetic connections with consideration of their operating conditions in flight.

He proposed the use of internal pressure in the rocket to increase its strength and examined the problem of maintaining and controlling pressure drops within the most suitable limits, which, in turn, he related to the problem of decreasing the passive weight of the rocket at the end of burning. He investigated the conditions and possible regimes of rocket heating as the rocket moved in the dense layers of the atmosphere and proposed various schemes for cooling and heat protection.

As Tsiolkovskiy developed his self-contained rocket he never gave up the thought that flight velocities would be reached which would permit overcoming earth's gravity and manned flight in a rocket into space. This aspiration permeates through all of Tsiolkovskiy's works. His designs of sectional, multi-stage rockets, and rocket trains, which he pondered a very long time ago, are remarkable and grandiose.

This is what Tsiolkovskiy wrote in 1929 in his work "Space Rocket Trains":

"By rocket train I mean the connection of several identical jet apparatus moving at first along a track, then in air, then in the vacuum outside of the atmosphere, finally, somewhere between the planets or suns. /16

"Not only is a part of this train carried away into celestial space, but the remaining parts, not having sufficient speed, return to earth.

"A self-contained rocket must be given a large fuel supply to reach escape velocity; this hampers the construction of jet apparatus.

"A train makes it possible either to reach high speed velocities, or to limit oneself to a comparatively small supply of the blasting constituents."\*

- Tsiolkovskiy investigated the basic technical and flight characteristics and the initial data and parameters of sectional, multistage rockets in different versions.

It is difficult to overestimate the value of Konstantin Eduardovich's proposals for sectional, multistage rockets, and rocket trains. In essence this proposal opened space to man.

The foregoing individual sections of Tsiolkovskiy's works, which abound in a mass of technical details, proposals, and ideas, are organically related in his works with theoretical concepts and proofs. Very much of this is already being used and is in no way unusual and it is self-evident.

Indeed, isn't the use of a rocket as a flying vehicle, liquid oxygen as one of the fuel components, and, for example, gas rudders for flight control obvious now, in our time. And all this was proposed by Tsiolkovskiy 60 years ago when heavier-than-air craft still did not exist and a rocket was only a pyrotechnic toy.

Today the Soviet community is celebrating the One-Hundredth Birthday Anniversary of the outstanding scientific worker in the field of rocket engineering and astronavigation, Konstantin Eduardovich Tsiolkovskiy. Soviet scientists will remember and praise his ideas, labors, and works, and will creatively develop and continue them.

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The most interesting and fascinating section in the works of Konstantin Eduardovich is that pertaining to the problem of interplanetary travel. It would be more correct to say that almost all the works of Tsiolkovskiy are purposefully directed and related with the theme of interplanetary flights.

Even his works on jet apparatus for flight in the atmosphere Tsiolkovskiy regarded only as a step toward flight into space. He predicted that the era of propeller aircraft would be followed by jet stratoplanes and, finally, rocket trains of the future and artificial earth satellities in the form of habitable interplanetary stations.

With the appearance and development of the idea of sectional, multistage rockets, and rocket trains, the problem of space flight with the use of presently known chemical energy sources became a sufficiently real technical problem.

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K. E. Tsiolkovskiy: Collected works, Vol. II, pp. 299-300.

Tsiolkovskiy conducted extensive investigations and calculations pertaining to problems of flight of an interplanetary rocket beyond the limits of earth's gravity, its further motion in free space, and the possibility of return to earth. He determined the optimal conditions of such flights under the most diverse variants and with different initial data.

Tsiolkovskiy was the first to investigate various trajectories and characteristics of different orbits of space rockets during takeoff from the earth and from the surface of planets and asteroids.

He examined the probable life conditions of future interplanetary travelers in a rocket. To protect people against the effect of acceleration during takeoff and braking of the rocket, he proposed to submerge them in special suits into tanks with a liquid having a density close to the density of the human body.

Foreseeing that a long stay in a medium without gravity would be difficult for the human organism to endure, Tsiolkovskiy proposed to create an artificial field of gravity during flight in an interplanetary rocket or artificial earth satellite.

Tsiolkovskiy again returned to the idea of using the sun's radiant energy for supplementing the energy reserves of an interplanetary rocket and for using this energy on an artificial interplanetary station, especially if it was inhabited for a long period of time.

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The problem of available energy supplies became especially acute to Tsiolkovskiy in connection with the development of the problem of returning to earth, or, if the need arise, landing on one of the planets with subsequent takeoff from it and then descent to the earth.

Tsiolkovskiy proposed a very interesting solution to the problem of landing a rocket on the earth almost without the consumption of fuel. In this case, the rocket, entering the earth's atmosphere, is braked, moving over an orbit around the earth for a time sufficient for the enormous entry velocities to decrease while maintaining in so doing regimes of heating and g-forces during deceleration acceptable for the rocket. This idea was later developed by Yu. V. Kondratyuk, a follower and pupil of Konstantin Eduardovich.

Tsiolkovskiy placed strong emphasis on the problem of developing interplanetary stations. In solving this grandiose problem he saw not only the enormous fundamental facilitation for heights of space rockets, which according to his opinion should be based on these stations, not only a magnificent scientific achievement, but also the possibility of realizing his long-held dream of man's actual conquest of solar space.

Tsiolkovskiy proposed to construct the interplanetary station itself out of several rockets connected together after entering orbit; it was to be well-equipped, spacious, flooded with sunlight, and without the burdensome restrictions of earth's gravity.

By burning a small quantity of fuel, as the need arose, it was proposed to change the orbit of the interplanetary station. Communication of the station

with the earth, according to Tsiolkovskiy, could be maintained by special rockets.

Takeoff of space rockets from the region of the interplanetary station would occur under greatly facilitated conditions, just as their landing upon return, since it would be possible to add to the rocket fuel stored beforehand on the interplanetary station.

Tsiolkovskiy proposed a scheme of a heating device providing different temperatures in the living quarters of the interplanetary station, using solar heat.

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Here is what he said with respect to this: "The opaque part of the living quarters is black on the outside. At a small distance from it is a second skin shiny on both sides. Its parts can rotate and become normal to the surface like the quills of a porcupine. Then a lower temperature is obtained. When this armor covers the black surface, a higher degree of heat is obtained. This skin can also be placed on the transparent part of the living quarters. Then a lower temperature can be produced. Depending on the purpose of the ethereal chambers, their construction can be very diverse.

"...At first there will be simple homes suitable both for people and for plants. They will be filled with oxygen having a density of 1/5 of the atmosphere, a small quantity of carbon dioxide, nitrogen, and water vapor. Here will be some fertile and moist soil. It, illuminated by the sun and sown, can produce root crops and other plants rich in nutrients. People by their respiration will spoil the air and eat the fruits, but the plants will purify the air and produce fruits."\*

"The energy of solar rays can be used for existing for an indefinitely long time without an atmosphere or planet. Just as the earth's atmosphere is purified by plants by means of the sun, so also can our artificial atmosphere be regenerated....Just as there is an infinite mechanical and chemical turnover of matter on the earth's surface, so also can this turnover be accomplished in our small world....

"[Calculations show] that one square meter of greenhouse facing sunlight is sufficient to feed a man. But who prevents us from taking a greenhouse having an enormous surface in a compacted form, i.e., in a small volume!?

"When circular motion around the earth or sun is established, we will assemble and move out from the rocket our airtight cylindrical boxes with diverse plant sprouts and suitable soil."\*\*

Thus, the necessary life support conditions will be provided on an interplanetary station for a sufficiently long time.

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\*K.E. Tsiolkovskiy: Collected works, Vol. II, p. 253.

\*\*K.E. Tsiolkovskiy. Collected works, Vol. II, pp. 128-130.

But gravity! Is it a necessary condition for plant life? In all probability no, because as experiment shows a change in direction and of the force of gravity by centrifugal force does not destroy the process of plant life.

Tsiolkovskiy did not doubt the possibility of man living in space provided certain conditions were created.

Rockets were known and the launching of pyrotechnic rockets had been observed by many long before Tsiolkovskiy. However, only Tsiolkovskiy proposed a jet apparatus similar to a rocket as a new and technical means for achieving unprecedented speeds and heights and for takeoff into the boundless world of the cosmos. Herein lies the greatness of Tsiolkovskiy's talent, his exceptional originality and distinction.

Tsiolkovskiy expanded the limits of human knowledge, his ideas about penetrating space in a rocket are only now beginning to be recognized in all their grandeur.

Konstantin Eduardovich labored the greater part of his life, under the severe situation of Tsarist Russia, surrounded by an insurmountable wall of ignorance and indifference.

He wrote: "The main purpose of my life was to make something useful for people, not to waste the gift of life, to advance mankind if only a little bit. This is why I was not interested in whether bread or help was offered me. But I hope that my works, perhaps soon and perhaps in the far future, will give society a mountain of bread and a store of power."\*

The Great October Socialist Revolution was that powerful force which inspired the 60-year-old Tsiolkovskiy with new creative daring and offered him unheard of opportunities. His name and his works have become known and are close to the Soviet people. In his declining years, suffering with disease, Konstantin Eduardovich took to his work with great enthusiasm.

He lived long enough so that his cherished thoughts of rockets and man's exploration of stellar space ceased to be considered an unrealizable fantasy and became a scientific and technical problem of our time.

Tsiolkovskiy bequeathed all his works on aviation, rocket navigation, and interplanetary communications to the Bolshevik Party and Soviet power--the true leaders in the progress of human culture.

Today we can say that the scientific legacy of Tsiolkovskiy, given to the Bolshevik Party and Soviet power, is not being left on the shelf and is not being utilized dogmatically, but is being creatively developed and successfully continued by Soviet scientists.

At present, obviously, it is still impossible to fully evaluate the entire

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\*K. E. Tsiolkovskiy. First Model of a Purely Metallic Aeronaut of Corrugated Iron. Kaluga, p. 1, 1913.

significance of the scientific ideas and technical proposals of Konstantin Eduardovich Tsiolkovskiy, especially in the area of penetration into interplanetary space.

Time sometimes inexorably wipes out the traces of the past, but the ideas and works of Konstantin Eduardovich will always attract increasing attention as rocket engineering develops.

Konstantin Eduardovich Tsiolkovskiy was a man who lived long before his era and we should recognize him as a true and great scientist.

## THE FIRST ROCKET AIRCRAFT IN THE USSR\*

K. I. Trunov

ABSTRACT. The activity of S. P. Korolev, designer of gliders that could carry rocket engines; the SK-9 (with engine the RP-318-1) rocket-propelled glider equipped with the RDA-I-150 rocket engine was successfully tested on February 28, 1940, by test pilot T. Fedorov.

The glider "Koktebel'" was presented in 1929 at the Sixth All-Union Glider Competition held in Crimea and caused bewilderment in the participants of the competition. On one hand, this glider was distinguished by its beautiful aerodynamic forms and, on the other hand, had the largest load per square meter, 18.8 kg. It was 50-90 kg heavier than its competitors. It contradicted the basic laws of gliding, since it was considered that for good soaring a glider should have a small weight and small load per square meter. The designer of the glider, Sergey Pavlovich Korolev, tested it himself, remaining in the air 4 hours and 19 minutes. The glider flew no worse than its lighter competitors, had a high horizontal speed, good stability, and was quite controllable.

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Why the designer of the "Koktebel'" glider increased the wing load remained incomprehensible to all.

In 1930 the participants of the next, Seventh All-Union Glider Competition were startled by the data of S. P. Korolev's glider "Krasnaya Zvezda" (SK-3). This glider had a load per square meter of 22.5 kg. This was so unusual that it was doubted whether the glider "Krasnaya Zvezda" could soar in the air at all. The weather prevented the competitions. Finally, on October 28 the wind started, reaching 15 m/sec, but the stream was so narrow that it did not permit going any distance from the mountains. All the gliders descended, and only the glider "Krasnaya Zvezda" remained untested since the designer and pilot of this glider S. P. Korolev was ill. Pilot Stepanchenok, head of the flight unit of the rally, took it upon himself to test the machine. He rose in the glider, "Krasnaya Zvezda," made a steep turn, and flew along the mountainslope. Soon he gained an altitude of 300 m, after which, unexpectedly for the spectators, he began to dive steeply. A commotion broke out on the glider field since everyone had decided that a crash was imminent. But, 100 meters from the earth, the glider abruptly soared upward and made a right loop. Then followed a gain in altitude and a second and third loop. This was unprecedented and unheard of. For the first time in the world not one but three loops were performed on a glider in free flight. The pilots very highly evaluated this achievement for its true worth. The possibility was open for teaching student pilots acrobatics in gliders. It seemed that the key to understanding why the glider designer

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\*Report given on March 22, 1965 at the 73rd session of the Section for the History of Aviation and Astronautics of the Soviet National Union of Historians of Science and Technology.

increased the load on the wing of his gliders was found. But actually, this was far from so. The reason was uncovered many years later.

During the period from 1930 to 1935, S. P. Korolev constructed a number of gliders. The last glider, SK-9 (the same as the RP-318-1), was constructed by him in 1935. This was a two-seat cantilever monoplane. It performed long towed flights (Moscow-Crimea). The load per square meter of this glider was 25.9 kg.

Only with the appearance of the SK-9 glider was the thought of the glider's designer, which he had nurtured from 1929 and for which he had so carefully prepared, finally formulated. S. P. Korolev intended the SK-9 for installation of a rocket engine on it. For this purpose the load per square meter of wing was increased from glider to glider. This was an extremely bold idea, if we recall that in 1929 F. A. Tsander had just performed the calculation of his rocket engine, and at the end of 1930 began to test it. The glider designer had not only to foresee far ahead, but also had to be firmly convinced of the future of rocket technology.

The first half of the 1930s marked the beginning of bustling activity in the USSR in the area of rocket technology. Numerous units and groups consisting of young enthusiasts of rocket engineering were engaged in developing rocket engines. Following the first liquid-fuel jet engines, developed and manufactured in the USSR in 1930-1931 at the Gas Dynamic Laboratory (GDL) and later at GSJP, several dozens of rocket engines of different schemes and designs were constructed during the first half of the 1930s. True, these engines were far from perfect, some exploded, but they nevertheless worked, and of course, aroused the thought of their use in flying machines. One such attempt, carried out by a group of rocket enthusiasts, deserves particular attention since it gave rise to great progress in the development of rocket engineering.

At first, as a first experiment, it was proposed to install F. A. Tsander's rocket engine on B. I. Charanovskiy's "Flying Wing" RP-1 glider, which had been constructed in 1932. However, this work was not brought to completion, as a consequence of which the flight could not take place. The SK-9 glider proved to be the only one suitable at that time for installing the rocket engine. Even a place for the fuel tanks of the rocket engine was provided for on the glider.

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At first it was proposed to mount the ORM-65 engine, developed by workers of the GDL, on the glider, but then it was decided to mount this engine on a winged rocket and another engine was manufactured for the glider. A year and a half was spent constructing the new engine. It was finished in 1939 and had the designation RDA-1-150 No. 1.

In view of the long time that had passed since the manufacture of the SK-9 glider, it was subjected to a thorough examination, its strength calculation was analyzed, and it was turned over for the expert advice of the Central Aerodynamic Institute. The detected defects of the glider were eliminated. Skis and a cowl for the rocket engine were additionally manufactured since these were completely absent.

Four test flights were carried out on the glider to check its flight data, and five ground tests of the rocket engine installed on the glider were made.

The equipment of the engine consisted of the rocket engine fastened on a special frame at the end of the fuselage, fuel lines passing inside the tail part of the fuselage; tanks installed behind the pilot's seat and at the place of the second seat; battery tanks fastened in the wing center section; electrical batteries fastened in the nose part of the fuselage; and instruments on the instrument panel to control the operation of the rocket engine. This installation caused a change in the outside shape of the glider only in the rudder section. The equipped glider had all elements of an aircraft with a rocket engine. The data of the SK-9 glider and the RDA-1-150 engine were as follows:

#### Glider

		SK-9 (without engine)	RP-318-1 (with engine)
Wing span	m	17	17
Wing area	m <sup>2</sup>	22	22
Load per square meter	kg	25.9	30.5
Length	m	7.28	7.28
Aspect ratio		13	13
Takeoff weight	kg	570	670
Weight of rocket installation	kg	-	100
Tank capacity	liter	-	60

#### Data of RDA-1-150 Engine

Thrust max.	kg	140
min.	kg	70
Consumption per second		
at maximum P	kg	0.75
at minimum P	kg	0.5
Pressure of fuel delivery		
max/min	atm	35/13

Testing of the rocket aircraft was given to one of the best glider pilots, Vladimir Pavlovich Fedorov. He was warned that this could be far from a safe flight. Fedorov, however, knowing all the possible dangers which could occur during the test, nevertheless without any doubts agreed to test it. Afterward he so loved the work of a test pilot that he devoted himself to this occupation entirely.

Before us lies a copy of the preliminary report on the test. Although it is printed on yellow, stiff wrapping paper, it fixes the day of the great achievement of the Soviet Union, the day February 28 1940, the first free flight of a glider with a rocket engine. Here is what the excerpts from record No. 6 of this report say:

## FLIGHT MISSION

To tow glider 318 at  $H = 3000$  behind an aircraft, to switch on the rocket engine. To hold the speed at or below 160 km/hour.

To keep the pressure in the combustion chamber of the rocket engine at 10 atm, which corresponds to 70 kg of thrust. To keep the engine operating until the fuel is used up. To fly with the engine operating along a straight line with a gain in altitude.

Glider 318 was filled with fuel components: 10 kg of kerosene, 40 kg of nitric acid.

Glider 318 was tested by test pilot Comrade Fedorov.

The crew of P-5 consisted of pilot Fikson, chief engineer of the rocket engine Comrade A. P. Pallo, and chief engineer of KB-29 Comrade A. Ya. Shcherbakov.

Before the flight the committee of the Technical Council of the People's Commissariat of the Aviation Industry granted the permission to fly with switching on of the rocket engine in the air, which was formulated by a written statement.

Glider 318 behind the P-5 towing aircraft took off at 1728 and gained an altitude of 2800 m in 31 min; glider 318 was disengaged by pilot Fedorov, after which he began to perform the mission.

Pilot Fedorov reported on the results of performing the mission as follows: /26

After disengaging the tow line for gliding, I established the direction of flight at a speed of 80 km, waiting for the P-5 aircraft observing me to approach, and began to switch on the rocket engine.

The rocket engine was switched on according to instructions. Starting of the rocket engine occurred normally. All control instruments worked well. The rocket engine was switched on at  $H = 2600$  m.

A smooth, not abrupt noise was heard after switching on the engine.

Upon establishing a pressure of 12 atm in the combustion chamber, which corresponded to a delivery pressure in the fuel tanks of 22-24 atm, the rocket engine had a smooth operating regime which held until complete consumption of the fuel components.

Approximately 5-6 seconds after switching on the rocket engine the speed of the glider increased from 80 km to 140 km, after which I set a flight regime with a climb to 120 km and held it until the end of operation of the rocket engine. According to the readings of the variometer, the climb occurred at a rate of 3 m per second. During the 110-sec period of rocket operation there was a 300 m gain in altitude. When the fuel components were consumed, the fuel stopcocks were closed and the pressure removed, which occurred at  $H = 2900$  m.

After switching on the rocket engine the acceleration occurred very smoothly. During the entire operation of the rocket engine I did not notice any effect on controllability of glider 318. The glider behaved normally, vibrations were not perceptible.

Acceleration from the operating rocket engine and its use for climbing left a very pleasant sensation in me, the pilot. After switching off the rocket engine, the descent occurred normally. During descent there was a number of deep spirals and tactical maneuvers at speeds from 100 to 165 km. The calculation and landing were normal.

The flight occurred under the following temperature conditions:

Ground temperature, 5.6°C

Temperature at H = 2900, 2°C

Ground wind, southwest at 5-7 m per minute

The crew observing from the P-5 airplane, Comrade Fikson, Comrade Shcherbakov, and Comrade Pallo, observed the following:

When pilot Fedorov switched on the rocket engine a small cloud of smoke from the ignition grain was noted, then the flame of the starting jets which left behind a trail in the form of a light-gray stream, after this the flame of the starting jets disappeared and a tongue of flame 1-1.5 m long appeared from the operation of the rocket engine on the basic components.

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The operation of the rocket engine on the basic components also left behind a light trail in the form of a light-gray stream, which rapidly scattered. Combustion of the fuel components in the rocket engine was complete.

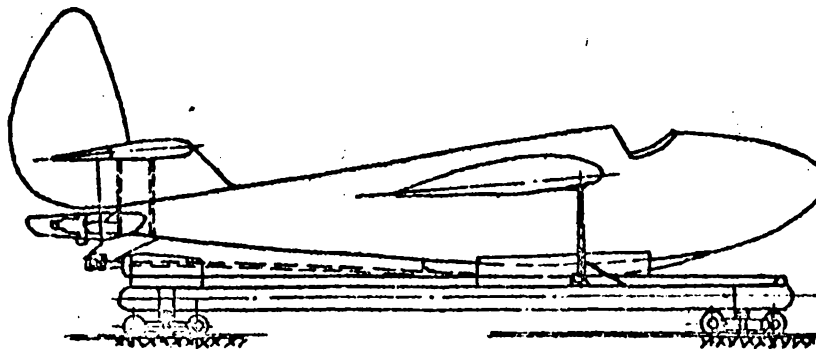


Diagram of rocket aircraft RP-318-1

Following the startup of the rocket engine we observed that glider 318 rapidly accelerated in horizontal flight and then began its climb. While endeavoring to maintain a constant distance with glider 318 to conduct observations, the aircraft P-5 dropped behind glider 318 despite a maximum increase of motor revolutions.

The operation of the rocket engine, which we observed, occurred smoothly from beginning to end. Starting up occurred normally. From the aircraft P-5 we could hear no noise from the rocket engine.

All those observing from the ground, including members of the Commission of the People's Commissariat of the Aviation Industry, saw at the initial instant of starting up of the rocket engine a cloud of smoke, after which the tongue of flame was even during the entire time of engine operation, which was accompanied by an even noise clearly audible on the ground. As the rocket engine ceased to operate, a small yellowish cloud, which quickly dissipated, was observed.

#### RESOLUTION OF THE COMMISSION

On the basis of discussing the rocket-engine flight and exchange of opinions with the technical commission of the People's Commissariat of the Aviation Industry, the latter decided to continue flight tests according to the established program.

The glider smoothly landed at a prescribed point. A group of future scientists and designers surrounded the pilot, each wanted to inquire personally how the flight was, how the glider and engine behaved. This was the first controlled flight with a liquid fuel rocket engine. It opened a new era.

Prior to this flight what was known abroad in this area? A glider flight was accomplished in 1928 in Germany by Stamer on a solid propellant engine, which gave momentum to the glider, after which the glider flew by inertia. These two flights are incomparable. In the USSR a rocket aircraft flew with a controlled engine which operated 110 seconds, whereas the longest duration of burning of Stamer's rocket did not exceed 30-40 seconds. Stamer's experiments ended with the glider burning.

In 1937 the Heinkel Company in Germany made the first flight tests of a liquid fuel rocket engine on the H-112 aircraft. Here the liquid-fuel rocket engine was installed in the tail of the aircraft as an additional engine to the main, piston engine. Consequently, this was not a free flight. Flight tests were terminated owing to the aircraft crashing during a forced landing.

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During 1934-1940 flights tests of a liquid-fuel rocket engine designed by Dalmeyer were carried out in Germany on the He-111 aircraft. The operating time of the engine did not exceed 30 sec. The engine was supposed to be used as a starting booster.

In 1939 the Heinkel He-176 completed its first rectilinear flight in Germany lasting 50 sec with a Walter HWK R-1 liquid fuel rocket engine; however, work on this aircraft was later stopped.

The flight of S. P. Korolev's Soviet rocket aircraft RP-318-1 was exceptionally important for the development of Soviet rocket engines, for future ballistic rockets, and carrier rockets. Everyone saw with their own eyes that the time for the practical use of rocket engines was quite close. The flight in 1942 by pilot G. Ya. Bakhchivandzhi on the BI-1 aircraft confirmed this. Following him came the remarkable achievements of the Soviet people in space, which began with the launching of the world's first artificial satellite designed and constructed under the supervision of S. P. Korolev.

On February 28, 1940, 25 years ago, the modest first flight of the rocket aircraft RP-318-1 proved to be the spark which gave rise to the flame of great achievements of the Soviet people in space. We will always remember this, we will always remember the glider creator--S. P. Korolev.

ALL-UNION CONFERENCE ON THE USE OF JET  
AIRCRAFT IN MASTERING THE STRATOSPHERE\*

Yu. V. Biryukov

ABSTRACT. The First All-Union Conference on Use of Rocket-propelled Flight Apparatus for Conquering the Stratosphere was held in Moscow, March 2-3, 1935. The introductory report was given by M. K. Tikhonravov; it was an analysis of the present state of rocket technology. S. P. Korolev reported on the progress being made in designing of rocket planes. V. P. Vetchinkin reported on rocket dynamics. Other reports covered gas and aerodynamics, wind tunnels, jet fuel, and flight medicine.

The conquest of unknown spaces was always and remains that part of human activity which especially attracts the attention of broad masses of people. The first half of our century was a time when man conquered the air ocean, penetrating ever higher into its "depth," and the stratosphere was the main line of this attack. Particular attention was devoted to conquering the stratosphere in the 1930s, when each event of "storming the stratosphere" became an event in the public life of the country. One such event was the First All-Union Conference for the Use of Jet Aircraft in Mastering the Stratosphere, which was held by the Jet Research Institute and Stratosphere Committee of AviaVNITO a year after the First All-Union Conference for the Study of the Stratosphere, convoked by the USSR Academy of Sciences, was successfully held. The founder of astronautics, K. E. Tsiolkovskiy, was invited to this conference, and then was elected Honorary Chairman of the Presidium. Although the great scientist could not be present at the conference, he ardently welcomed and highly esteemed its work. /30

The First All-Union Conference for the Use of Jet Aircraft in Mastering the Stratosphere was held in Moscow at the Central House of the Red Army on March 2-3, 1935. In all, there were three sessions and 50 reports were heard. When setting out to briefly review these reports, it is necessary to note that, despite the survey character of these reports, not one of them was of a random, abstract nature, but backed up by a specific direction in the investigations that had been carried out and, what is especially important, all reporters supported the "establishment only on real things, on scientifically founded and not on fantastic prospects."\*\*

M. K. Tikhonravov, engineer of RNII and the designer of the first Soviet liquid fuel wingless rockets, in his introductory report, "Prospects of the \*Report given on March 22, 1965 at the 73rd session of the Section for the History of Aviation and Astronautics of the Soviet National Union of Historians of Science and Technology. /31

\*\*Tekhnika vozdushnogo flota, no. 7, p. 35, 1935.

Development of Rocket Technology and Conquest of the Stratosphere"\* gave a detailed review of the state of rocket technology of that time and specifically examined the problem of the rapid development of stratosphere rockets.

The first part of the report even today can serve as a true specimen of scientific popularization of rocket technology. Arguing against the opinion extremely widespread in the popular literature at that time that "by means of a rocket engine it is possible to achieve colossal gains in almost all areas of technology and that it should replace all other less advantageous engines"\*\*, the reporter indicated that despite the fact that "the appearance of a liquid fuel rocket engine is a factor of progress in modern technology, this engine can in no case replace a single one of the existing types of engines in the areas of use of which it will be less perfect and less advantageous.

The appearance of the rocket engine opens new means for travelling in those spaces of our world and the universe which are inaccessible at present to aircraft equipped with any other engine."\*\*\*

Further, Tikhonravov scientifically demonstrated that the rocket engine is an engine of high speeds. And all attempts to use it in ground transportation are associated either with certain publicity purposes, or attributed to the inadequate scientific and technical knowledge of the inventors. The effective area of use of a rocket engine is "where it will give us an advantage over others, namely in stratosphere and extraatmosphere transportation."\*\*\*\*

In passing, Tikhonravov dwelled on the prospects of the development of the jet engine. He said: "...we have at hand not only the theory of such an engine (developed by Prof. Stechkin) but also the practical proposals on the scheme of its construction (engineer Tsander, and others). We can hope that complete attention is not devoted to this engine on the part of the workers of our motor industry...in the future the role of the jet engine in the development of stratosphere transportation will be most significant."\*\*\*\*\*

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Evaluating the possibilities of a rocket for stratosphere exploration, the reporter noted that a rocket for altitudes above 30-40 km will be the main and only means of exploration, whereas indirect methods of investigation, actinometric, acoustic, and astronomic, are already supplementary to rocket exploration.

Of particular interest is the second part of the report. Here a method for the design and ballistic analysis of a rocket is presented for the first time for a simple case: vertical flight of a single-stage liquid-fuel rocket. Weight characteristics of individual elements of the rocket structure were presented, its weight equation was constructed, and graphs of rocket climb as a function of the ratio of masses, discharge velocity, and initial rocket mass are given.

\*Tikhonravov, M. K.: Use of Rockets for Exploring the Stratosphere. Rocket Technology (Raketnaya tekhnika). Moscow-Leningrad, pp. 18-33, 1936.

\*\*Ibid., p. 18.

\*\*\*Ibid., p. 18.

\*\*\*\*Ibid., p. 19.

\*\*\*\*\*Ibid., p. 20.

An analysis performed by the reporter showed that the level achieved by rocket technology in 1935 permits developing a stratosphere rocket of a simple design with a high-pressure air container with the following characteristics:

Initial mass 200 kg  
Design mass 69 kg  
Mass of useful load (instruments, parachute) 9 kg  
Mass of fuel 122 kg  
Exhaust velocity 2000 m/sec  
Maximum height of rise 45 km

The design of such a rocket was examined.

Later, M. K. Tikhonravov dwelled in detail on the problem of increasing the maximum altitude and indicated what would result from an increase of the exhaust velocity and decrease in the relative weight of the structure and how these improvements of the rocket parameters could be achieved. It was indicated that in the near future an altitude of more than 500 km could be achieved by a single-stage rocket with the use of pump delivery, and even a greater altitude by means of sectional rockets. The reporter noted the value of the proposals by V. P. Vetchinkin, Yu. V. Kondratyuk, and F. A. Tsander directed toward the development of ideas of sectional rockets, and at the same time indicated the considerable complexity of the technical solution to the problem of developing such rockets.

It is necessary to point out the fundamental thesis of the report relating technology of 1935 with the achievements of today: "Exploration of the stratosphere is not the end purpose of the development of rocket engineering. This is only a means to get firmly established, to prepare technically for man to rise at first into the upper layers of the atmosphere, then to go beyond it and find ways into space to other celestial bodies."\*

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Having touched upon problems of space flight, Tikhonravov discussed the prospects of using radiant energy, and primarily, solar energy as the prime mover of a space rocket. In passing it should be pointed out that at that time he had made a serious investigation of the use of radiant energy for space flight, in which a promising scheme of a nuclear-hydrogen engine operating on electrical energy produced by solar batteries was proposed for the first time, and design calculations of a rocket with such an engine for manned flight to the moon were first carried out. This investigation was published in 1936\*\* and now it should be regarded as a true landmark in the development of Soviet astronautics.

In concluding his report Tikhonravov pointed out the considerable attention which is being devoted to rockets abroad and expressed the conviction that "in the development of rocket technology the USSR, a country where socialism is being

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\*Ibid, p. 32.

\*Tikhonravov, M. K.: Ways of Utilizing Solar Energy for Space Flight. Jet Propulsion (Reaktivnoye dvizheniya). No. 2, Moscow-Leningrad, pp. 109-140, 1936.

built, a country of new technology, should be and will be in the front."\*

S. P. Korolev, engineer of RNII and leading designer of winged craft, gave a detailed report "A Winged Rocket for Manned Flight."\*\* The contents of this report are today of great historical interest since it presents for the first time, on a scientific basis, the features and possible scheme of a winged piloted rocket (rocket aircraft), its design weight analysis, and analysis of its flight characteristics.

Having indicated the failure of numerous attempts to install a rocket engine on an ordinary aircraft, i.e., the mechanical transfer of rocket engineering to aviation, the reporter showed that the specific characteristics and the dynamics of rocket aircraft flight, its trajectory, and its class result in the similarity between a rocket aircraft and a propeller aircraft being very negligible despite features in common with an ordinary aircraft. The rocket aircraft will have the classical cantilever monoplane configuration, with a wing of thick profile, centrally situated fuselage, with the tail assembly fastened to the end of the fuselage. The following external characteristics will be inherent to it: small span, small aspect ratio, and small size of the lifting surface. The fuselage will have an appreciable length and will be occupied mainly by the engine, tanks, devices powering the engine, etc. The wing will also be used for placement of various units of the engine, instruments, etc. As we see, in these words are anticipated the features of modern rocket aircraft (for example, the X-15).

It is interesting to dwell on the problems noted in the report which designers of rocket aircraft faced in 1935. Concerning these problems the reporter said that here "a powerful liquid fuel rocket engine occupies the main place. The realization of manned flight in a rocket aircraft depends directly on achievements in this area." Other urgent problems were: "a pressurized cabin: its considerable size, complexity of concluding any kind of control, and, mainly, its appreciable weight"\*\*\*; protection of the pilot against the harmful effect of large g-forces during flight; the need for achieving good flight characteristics and appreciable increase of initial weight of the rocket, with which is related the enormous "difficulty of developing and operating such a vast high-altitude craft and the extraordinary difficulties of working with vast quantities of liquid gases,"\*\*\*\* required as fuel for it.

Today we can say with pride in Soviet technology that all these then seemingly extremely difficult problems have been successfully overcome and are now behind us.

Having examined the characteristics of a rocket aircraft and the problems related with its development, the reporter moved on to a design analysis of its flight and weight characteristics. The numerous graphs illustrating this part of the report, compiled on the basis of specific design investigations carried out at that time at RNII, are of considerable interest since they very com-

\*\*\*Ibid., p. 36

\*\*\*\*Ibid., p. 44.

\*Tikhonravov, M. K.: Use of Rockets for Investigating the Stratosphere. Rocket Technology (Raketskaya tekhnika). Moscow-Leningrad, p. 33, 1936.

\*\*Tekhnika vozdushnogo flota, No. 7, pp. 35-56, 1935.

pletely reflect the real level of achievements of rocket technology of that time. As an example, we can indicate the graphs of the dependence of the weight of single-chamber and multichamber liquid fuel rocket engines on thrust, weight of tanks, on fuel supply, weight of the pump unit, on fuel consumption and supply pressure, maximum height of rise on ratio of masses, on initial thrust-weight ratio, etc.

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On the basis of this weight analysis, data of a simple winged rocket were presented for manned flight into the stratosphere under conditions of its minimum weight. This weight of 2000 kg was distributed in the following manner:

pilot in spacesuit	- 5.5%
engine	- 2.5%
high-pressure container	- 10.0%
tanks	- 10.0%
structure	- 22.0%
fuel	- 50%

Such a rocket could rise to an altitude of 20 km at a specific impulse of 250 kg-sec/kg and thrust of 2000 kg.

In the case of using pump delivery of fuel, its supply could be increased to 60% of the initial weight of the rocket. Calculations of the flight characteristics of the winged rocket were carried out by V. P. Vetchinkin's method. The following trajectory proved to be optimal with respect to the flight altitude: the rocket is accelerated along the earth by solid propellant boost motors to a speed of 80 m/sec, takes off, and begins to climb at an angle of 60° on the motor proper, after using up all fuel the rocket changes into vertical flight by inertia and reaches a height of about 32 km, then the rocket noses over, picking up speed, after which it changes into a gliding flight, reaching a range of about 220 km at a total flight time of 18 min. The trajectory optimal in terms of range gives 280 km and the trajectory optimum with respect to speed gives 600-700 m/sec.

In conclusion, the report examined, first, different schemes of prospective aircraft: sectional and compound. It was pointed out in particular that at altitudes up to 30 km jet engines are of exceptional interest and value for the flight of rocket apparatus. Second, craft with rocket engines designed for flights of a purely experimental nature at low altitudes were examined.

The first attempt to develop such a craft was the work performed in 1932-1933 at GSJP with B. I. Cheranovskiy's glider RP-1 (BICH-II) on which was mounted F. A. Tsander's OR-2 engine. Then work was not carried out to completion because of imperfections of the engine. The report pointed out the need for developing a new rocket aircraft-laboratory on which "a study of the operation of various rocket units in air could be systematically carried out. On it it would be possible to set up the first experiments with a jet engine and an entire series of other experiments, at first towing the craft to the necessary altitude. The ceiling of such a craft can reach 9-10 km."\*

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\*Ibid, p. 56.

As is known, such a craft, the RP-318, was soon developed at RNII after the design and under the supervision of S. P. Korolev. True, owing to abnormalities associated with the situation of the cult of personality, the rocket aircraft was flight tested only in 1940.

The conclusion of the report is interesting in that it is extremely characteristic for the entire style of work of the reporter at RNII as a whole, and therefore we will present it in its entirety.

"The winged rocket is of great importance for super-high manned flight and for stratosphere exploration.

"The task of the future is to master the principles of rocket technology by persistent daily work, without superfluous ballyhoo and publicity which is so often inherent, unfortunately, even now to many works in this area, and to study first the strato- and ionosphere. The task of the entire community, the task of Aviavnito and Osoaviakhim is to gain every kind of assistance in this area and to properly formulate the topics on rocket engineering for lower organizations of society and individual inventors and to intelligently popularize the ideas of rocket flight."\*

V. P. Vetchinkin, a professor at TsAGI, presented a major report on rocket dynamics.\*\* He familiarized the audience with his works on the construction and solution of equations of the vertical motion of a rocket with a high speed in a medium with variable density and showed that a rocket must develop a velocity of 3000 m/sec for vertical flight through the earth's atmosphere. Then he thoroughly examined the flight dynamics of a winged rocket, the construction and solution of equations of motion, including with consideration of drag at supersonic velocities and determination of the optimal parameters of the flight path. Vetchinkin dwelled with particular details on gliding dynamics from very high altitudes with consideration of the change of air density, energy of the aircraft, and curvature of the earth.

In conclusion, the reporter elucidated the difficulties of achieving escape velocities on the basis of Tsiolkovskiy's works.

The morning session of March 3 opened with vigorous debates, which showed that /37, the reports were made on problems vitally important for the development of our rocket technology. Especially interesting were the addresses of engineer A. G. Kostikov who dwelled on problems of accomplishing pump fuel supply to the liquid fuel rocket engine and problems of investigating Tsander's forward and reverse cones, of engineer S. A. Pivovarov on the problem of developing an automatic gyro and radio control of rockets, and of engineer-inventor P. I. Shatilov on the advantages of his scheme of a liquid fuel rocket engine. It is interesting to note that in the discussions two different views appeared concerning the prospects of rocket technology. Thus, for example, it was stated in one of the reports that an unreal problem was formulated in the work of V. P. Vetchinkin since motion with very high speeds was examined, whereas engineer G. E.

\*Ibid., p. 56.

\*\*Information on the reports and speeches not published in the press are presented on the basis of communications of the periodical literature and notes of the conference taken by M. K. Tikhonravov and stored in his personal archive.

Langemak, conversely, noted that the report gave very modest figures which can create a pessimistic mood, whereas reality promises more optimistic prospects for rocket technology.

The agenda of the second day of the conference began with a report of the outstanding Soviet gas dynamicist F. I. Frankl', professor of TsAGI, in which he presented a brief history and principles of gas dynamics. The reporter dwelled more thoroughly on his graphic method of calculating supersonic flows with axial symmetry and its applications to finding the most advantageous shape of the rocket engine nozzle. It is interesting that in his report Frankl' elaborated the problem of aerodynamic heating of bodies during their motion at high speed, which at that time had still not been brought up technically.

The reporter V. I. Dudakov, engineer at RNII and leading Soviet specialist in rocket acceleration of aircraft, examined the theory of starting with the use of rocket boosters and told about a technique for accomplishing such a start which was developed and realized at GDL on RNII.

The second report of Prof. Frankl' examined, from the aerodynamic point of view, the possibilities of Tsander's proposed combined engines consisting of an engine-propeller unit and examined the possibility of creating a rocket propeller.

Of great interest were the reports of workers of RNII on the first supersonic wind tunnels. Engineer M. S. Kisenko gave a review of all high-speed tunnels of that time. There were only 8 such tunnels in the world, of which three were in the USSR: one at TsAGI, another at the Khar'kov Aviation Institute, and the third at RNII. The last tunnel was thoroughly described by the author of the design and supervisor of the works on its development, Yu. A. Pobedonostsev. This tunnel made it possible to obtain an open air flow with a diameter from 40 to 60 mm at an absolute flow rate up to 900 m/sec under normal conditions (i.e., at a static pressure in the stream of 760 mm Hg and air temperature in the stream of +15°C) and up to 1100 m/sec at a low stream pressure. The design and construction of the tunnel and the method of experimenting in it were reported.\*

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The evening session began with a survey report of one of the leading engineers of RNII, the author of a variety of the first Soviet liquid fuel rocket engines, "Fuel for Jet Engines and Requirements on Materials for Engines and Rockets." In the examination of fuels particular stress was laid on high-boiling components and, primarily, on nitrogen-containing oxidants: nitric acid, nitrogen tetroxide, and tetranitro-methane. Examined in detail was the problem of igniting the fuel, and specifically, igniting by means of pyrotechnic grain, which subsequently became widely used. Speaking about the requirements on structural and insulating materials for a liquid fuel rocket engine, the reporter demonstrated for the first time to a large audience the burnt, exploded, and fused parts of engines, which convincingly confirmed his presented data.

Processes of burning in a jet engine chamber were examined in the report of A. V. Zagulin, scientific associate of the Leningrad Physicochemical Institute.

\*Pobedonostsev, Yu. A. and M. S. Kisenko: High-Speed Wind Tunnels. Rocket Technology (Raketnaya tekhnika). No. 2, Moscow-Leningrad, pp. 143-203, 1936.

The reporter noted that all works on burning were heretofore carried out by two separate ways. The first way was empirical design of machines in which the burning process should occur, and attempts to influence this process by changing the design. The second way, also in essence empirical, was to act on the very mechanism of burning without changing the design mainly by introducing various chemical additions. Now it has become clear that a third way can lead to the development of the theoretical basis for an efficient organization and control of the burning process: a detailed study of burning processes with a comprehensive consideration of the most diverse factors: chemical, structural, hydrodynamic, etc.

Having divided the burning process in a rocket engine into three stages: chemical processes before ignition, the formation of a flame, and the motion of the flame, the reporter examined each of these stages from the point of view of the theory of burning and made a number of important conclusions concerning the significance of the rate of entrance of the fuel components into the combustion chamber, significance of the induction period, effect of vorticity and dispersion of the working mixture, unsteady operation of the motor during starting and the effect of introducing active additives to the fuel on its operation. The report of Zagulin was of great value because he, on one hand, showed that Soviet specialists in rocket engines are basically following the correct way from a scientific point of view in developing liquid fuel rocket engines, and, on the other hand, served as an impetus for setting up at RNII a number of purposeful scientific investigations in the area of managing burning processes in liquid fuel rocket engines. Here it should be noted that the associates of the Leningrad Physicochemical Institute not only helped workers of RNII get on the scientific pathway in the area of studying burning but also derived much that was useful for their own work from their contacts with the rocket specialists, since during those years processes of burning of pure fuel in a pure oxidant at high consumptions per second could be observed at RNII.

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Biomedical problems were also examined at the conference. The report "Physiology of Manned Flight in a Rocket" was given by N. M. Dobrotvorskiy, chief of the laboratory of organization of flight duties at the Air Force Academy im. Zhukovskiy, a great enthusiast of this problem who has made a great contribution to the development of high-altitude and high-speed aviation medicine.

The work of the Jet Group under the military-scientific committee of the Central Council of Osoaviakhim was reported by its director I. A. Merkulov, and the work of the similar Leningrad Group was reported by engineer A. N. Shtern.

The reports made on the second day of the conference also evoked lively discussions. Particularly interesting was the speech of N. G. Chernyshev, engineer at RNII, who, arguing against the principal reporter on the problem of rocket fuels, stated that chemistry promises very great prospects with regard to rocket fuel, and dwelled in greater detail on the problem of using such promising components as ozone, silanes, and solutions of acetylene in acetone.

In conclusion the conference passed resolutions on all reports, which presented an expanded plan for the future works on the development of rocket technology and its application to conquering the stratosphere.

The First All-Union Conference on the use of jet aircraft for conquering the stratosphere was the world's first such forum of rocket engineers which discussed the most topical problems facing them and pointed out effective methods of solving these problems which had long impeded progress in the development of Soviet rocket engineering. Herein lies the great historical significance of the conference.

HISTORY OF DEVELOPMENT OF SOVIET SEAPLANE AVIATION\*  
(Period before the Second World War)

K. F. Kosourov

ABSTRACT. The report covers the development of the hydroplane in Russia and other countries before and after the Revolution.

Seaplane aviation arose in the first decade of the Twentieth Century, i.e., /40 about 30 years after the development of the world's first aircraft. The progress which aviation made in the first stage of its development served as an impetus for attempting to use it at sea. The use of the water surface as a natural airfield vigorously expanded aviation prospects. The seaplane could prove to be useful where there were rivers, lakes, or sea coast.

The first experiments of taking off from the water in Russia were in 1911. One of the pioneers and initiators of this event was Yakov Modestovich Gakkel', who since 1910 had already had experience in flying a land aircraft of his own design. To him belongs the honor of developing the first Soviet seaplane.

Prior to 1912 seaplanes in all countries were exclusively float planes. It was not easy to reject the idea of using a landing carriage and fuselage. The replacement of wheels by floats had as its sole object the accomplishment of takeoff from the water surface. The floats were distinguished by imperfection in the shape of the outlines and, from the point of view of seaworthiness, left much to be desired. Seaplanes were capable of taking off only on a quiet water surface. Even slight waves were an obstacle to takeoff, the floats often did not endure the dynamic loads of the water and broke. As an example we can name Fabre's floats (1910). They somewhat resembled a wing in shape, were flat-bottomed, relatively broad, and rectangular in plan. Structurally they consisted of a wooden skeleton covered with waterproof fabric.

Frequent accidents and poor seaworthiness of the first seaplanes necessitated a search for new ways for developing better designs. To solve to some extent the problem of seaworthiness, designers, of course, thought about using the experience of hydroplane shipbuilding and transfer to the area of seaplane aviation. As a result the flying boat was born, the shape of the lines of the nose part of which and the presence of steps resembled a high-speed hydroplane-launch. The high centering of the seaplane and high situation of the thrust lines, the need for changing the trim during the takeoff run and setting of the tail assembly, the facility for easy takeoff from the water, and aerodynamic requirements, i.e., everything that essentially distinguishes a seaplane from /41

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\*Report given on October 30, 1963 at the session of the Leningrad Branch of the Section on the History of Aviation and Astronautics of the Soviet National Union of Historians of Science and Technology.

a hydroplane could not help but effect a substantial modification of the body of the latter. However, the process of this modification was far from simple.

The first flying boats appeared in France in 1912. They belong to the category of biplanes with a pusher propeller and were the prototype of flying boats which became widely used and were retained in aviation for more than a decade. The shape of the body lines and the ratio of the main linear dimensions were retained without substantial changes almost to the beginning of the Second World War.

The flying boat constructed in 1912 by the French designers Donne and Levec were not noted for its seaworthiness. It was too blunt-nosed and had a flat bottom in the nose section, which promoted during the takeoff run the development of a bow wave and severe splashing. The step with respect to the center of gravity was too far forward. These defects greatly hampered takeoff.

The well-known Russian designer Dmitriy Pavlovich Grigorovich was able to successfully solve, in 1913, the problem of a flying boat. His first flying boat M-1 weighing 880 kg was equipped with a 50-hp motor, and in later models M-3 and M-4 with a 100-hp motor, and developed a speed of 100 km/hr, high for that time. It is necessary to point out that in speed competitions organized by the French at St. Malo, the seaplanes of foreign firms scarcely reached a speed of 85-90 km/hr.

Resting on his own construction experience and having an exceptional design flair, Dmitriy Pavlovich soon developed the flying boat M-5, which as early as 1915 was in the service of our naval aviation and participated in military operations on the Baltic and Black Seas. The boat had a 100-hp engine, a speed of 108 km/hr, ceiling of 4000 m, and duration of 5 hr. Many of our naval aviator graduates were taught on the M-5 seaplane, /42

The difficulties common to all aviation designers of that time were aggravated in the area of seaplane construction by the absence of developed methods of calculating the seaworthiness of a seaplane. The theory of hydroplaning still did not exist. Far from all means of ship theory could be used in seaplane construction owing to the specific characteristics of a seaplane. The experience in designing and operating high-speed launches, which did not have a very close hydrodynamic relation with seaplanes, was of little use. In spite of the difficulties, D. P. Grigorovich accepted the commission of the Naval Ministry to design and construct various types of seaplanes and proved to be capable of fulfilling it successfully. The seaplanes ordered by the Chief Naval Staff, were produced in series. D. P. Grigorovich's boat M-9 (1916) had such good seaworthiness and flight and tactical characteristics that the countries of the Entente obtained this seaplane from the Provisional Government of Russia.

From the historical point of view, D. P. Grigorovich's boat M-11 deserves particular attention, since it was not only the world's first naval fighter but also the world's first airplane with armor. The M-11 flying boat was armored in the nose section and at vital places.

In 1917 D. P. Grigorovich, together with M. M. Shishmarev and subsequently with Ye. I. Mayoranov, professor at the Red-Banner Order of Lenin Air Force Academy im. Prof. N. Ye. Zhukovskiy, constructed the world's first two-float torpedo plane for "GASN," which could carry an uncommon load for that time, a torpedo weighing 1 ton. In 1927, D. P. Grigorovich created a new machine "Explorer of the Open Sea" designated ROM-1 with an all-metal hull.

Design engineer V. B. Shavrov was the chairman of the light seaplane construction industry in the USSR. In 1929 he designed and built a light seaplane which was soon somewhat enlarged and batch produced in 1930. This miniature flying boat-amphibian with a 100-hp M-11 engine, called the Sh-2, is well known in aviation.

Several experimental seaplanes were created by K. A. Vigand and P. D. Samsonov, who in the 1920's, together with V. B. Shavrov, joined the staff of D. P. Grigorovich's design department.

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Soviet seaplane technology gained considerable experience in mounting land aircraft on floats. As an example we can point out the heavy bomber TB-1 designed by Academician A. N. Tupolev. This aircraft, named the "Country of the Soviets" piloted by Shestakov and Bolotov made the well-known round trip flight from Moscow to New York in 1929.

The name of A. N. Tupolev and his design team is associated with the construction of heavy seaplanes. Thus, in 1930 was constructed the two-motor flying boat ANT-8 which had, primarily, an experimental value. In 1934 two seaplanes were developed: MTB-1 and ANT-22. The first of these was a three-place monoplane with AM-34 engines mounted in three nacelles extended on props under the wing. The aircraft was intended for long operations over the sea and had, for that time, good flight characteristics and seaworthiness. The second, the two-hull seaplane ANT-22, had six AM-34 engines mounted above the wing in three tandem units. This aircraft could carry a bomb load of up to 6000 kg and had powerful armament. A world record for altitude with a load of 13 tons was set on the ANT-22 in 1936.

In 1937 appeared the amphibian ANT-44 which was a monoplane with four AM-85 engines situated in the wing. The retractable landing carriage enabled the machine to use the land and sea as an airfield. The ANT-44 aircraft was a heavy bomber and long-range reconnaissance aircraft. It was successfully used in military operations during the Second World War. The high flight and tactical characteristics made it possible to set six records on the ANT-44.

Engineer I. V. Chetverikov developed and built new types of seaplanes. His seaplane for a submarine deserves attention.

About 30 years ago the navies of some countries raised the problem of the possibility of equipping submarines with aircraft. If a seaplane could be selected from the existing type of machines for a cruiser or battleship, then the extreme limitation in the size of submarine hangar would require the development of a specially designed aircraft. The problem of such an aircraft was successfully solved by I. V. Chetverikov, and his seaplane was exhibited at

the International Exhibit in Milan in 1936. The seaplane had a collapsible engine truss, folding wings, cantilever parts of the horizontal tail surfaces and props of the wing float. Its flying weight was 800 kg.

We need point out I. V. Chetverikov's flying boat ARK-3 which was designed for servicing Arctic regions. Two world records for altitude while flying with a load were set on this machine.

We owe the appearance of many successful types of seaplanes to the fruitful activity of G. M. Beriyeve. His flying boat MRB-2 with an AM-34 engine gained great popularity in naval aviation. Thanks to its high performance, this boat remained in the navy for a long time. G. M. Beriyeve also developed naval reconnaissance aircraft and ship-borne aircraft.

From the first flying boat of D. P. Grigorovich to the heavy multi-engine air cruiser of A. N. Tupolev -- this is the historical path of development of Soviet seaplanes.

The start of the development of theoretical problems of the hydromechanics of seaplanes dates to the middle of the 1920's. The first theoretical solution to the problem of planing of a flat or slightly curved plate moving at a small angle of attack in a plane-parallel flow of an ideal fluid was obtained in the USSR by active member of the Ukrainian SSR Academy of Sciences G. Ye. Pavlenko. Three years later Academician G. Ye. Pavlenko, proceeding from other physical concepts, gave an approximate theory of planing of a body having a finite width.\*

In this last theory the development of dynamic pressure on the bottom is regarded as a consequence of the continuous overcoming of the inertia of the water masses, which, as the body moves, is displaced downward and to the side at a rate larger, the greater the speed of the body and the greater its angle-of-attack. This theory enabled G. Ye. Pavlenko to solve the problem of the rebound of a body from the free surface of a liquid.\*\*

The theoretical works of Academician L. I. Sedov occupy a prominent place. /45 His numerous published works are devoted to problems of hydrodynamics. Of considerable interest are his works on the theory of the impact of a solid on water and on the theory of planing. Such works, for example, of L. I. Sedov as the "Theory of Unsteady Planing and Motion of a Wing with Trailing Vortices"\*\*\*\* and "The Plane Problem on Gliding Over the Surface of a Heavy Liquid"\*\*\*\*\* are fundamental works which affirm the leading role of the Soviet school of hydromechanics in this area of scientific knowledge.

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\*Pavlenko, G. Ye.: Principles of Planing Theory. Proceedings of the Research Aero-Institute GVF (Trudy Nauchno-issledovatel'skogo Aero-Instituta GVF). Article 20, Leningrad, 1932.

\*\*Pavlenko, G. Ye.: Phenomena of Rebound on the Water Surface, Morskoy sbornik, No. 1, 1932.

\*\*\*Trudy TsAGI No. 252, 1936.

\*\*\*\*Proceedings of the Conference of the Theory of Wave Resistance (Trudy konferentsii po teorii volnovogo soprotivleniya). Izd. TsAGI. Moscow, 1937.

The world's first problem on the theory of the impact of a solid against a liquid was solved by Professor N. Ye. Zhukovskiy in 1883. Further investigations of the phenomenon of impact were renewed only after almost 50 years and were brought about by the requirements of seaplane construction. Independently of the works carried out in the USA by Thompson, N. N. Podsevalov on the initiative and assignment of TsAGI carried out tests on the Black Sea and in 1931 published a report on an investigation of water pressure on the bottom of seaplanes. Experimental works were combined with theoretical investigations. Soon a number of theoretical works on impact theory appeared in the Soviet literature. Their authors were Academicians M. V. Keldysh, M. A. Lavrent'yev, and L. I. Sedov, as well as other researchers, mainly workers at TsAGI who substantially broadened this region of hydrodynamics.

In a brief outline it is not possible to enumerate or evaluate all, even basic works, which belong to the pens of our scientists.

All these works determine the major contribution of Soviet science to seaplane aviation and hydrodynamics.

We can only state that Soviet scientists have occupied a leading place in all the principal sectors of seaplane science.

## CHRONICLE AND INFORMATION

### AT THE SECTION OF THE HISTORY OF AVIATION AND ASTRONAUTICS

Twelve sessions of the Section of the History of Aviation and Astronautics, /46 at which 19 reports and communications were given, was held in Moscow between October 26, 1964 and December 6, 1965.

The 67th session of the section held on October 26, 1964 was devoted to an examination of the problem of compiling a chronicle of astronautics (the report of I. Ye. Mosolov) and to analysis of G. Obert's suggestion (1929) of creating "electrical" spacecraft (the communication of V. I. Belolipetskiy).

The section examined the work of I. Ye. Mosolov on compiling a chronicle of astronautics and recommended its continuation; at the same time, the section passed a resolution to begin work on compiling a scientific and technical chronicle of astronautics reflecting the development of science and technology in space research.

Having discussed V. I. Belolipetskiy's communication on the little-known proposal of G. Obert in 1929, which played an essential role in the development of electric rocket engines, the section recommended translating this material into Russian and printing it in the publications of the section with necessary commentaries.

The 68th session of the section, held on November 10, 1964 was devoted to the 75th Birthday Anniversary of Academician B. N. Yur'yev. Academician M. D. Millionshikov, Vice-president of AN SSSR gave the opening address speaking on the life and creative pathway of B. N. Yur'yev. Friends and pupils of B. N. Yur'yev told about his scientific, pedagogical, and social activity. A detailed report on this session of the section is published in "Problems of the History of Science and Technology" (Moscow, No. 20, 1966).

On November 30, 1964, at the 69th session of the section, Prof. I. I. Anureyev, Doctor of Military Sciences, Major General of ITS, gave a report on the trends in the development of aircraft as strategic weapons.

Noteworthy dates in the history of aviation and astronautics in 1965 were /47 examined and confirmed at this session.

The 70th session of the section, devoted to the display of matters pertaining to the history of aviation and astronautics in Moscow and Leningrad Museums, was held on December 25, 1964.

N. N. Femenkevich, a scientific coworker of the Museum familiarized the audience with the research works carried out at the M. V. Frunze Central House of Aviation and Astronautics.

T. L. Volkoviskaya, Director of the Department of Astronautics of the Polytechnic Museum told about the exhibits on astronautics at the Polytechnic Museum.

I. Ya. Shatoba, Deputy Chairman of the Section of the History of Aviation and Astronautics of the Leningrad Branch of the Soviet National Union of Historians of Science and Technology, gave a report on the organization of a "park of cosmonauts" with a pavilion of the history of aviation and astronautics in Leningrad.

Measures for creating in Moscow a Central State Museum of the History of Aviation and Astronautics and an archive for it was supported at the session of the section.

On January 28, 1965, at the 71st session of the section, results of scientific investigations into various problems of the history of space research were heard.

R. G. Bazurin spoke about space research and certain problems of developing modern science. V. I. Belolipetskiy spoke about problems of the development of the mechanics of small-thrust space flight (prior to the 1930s). I. N. Bubnov gave a report on problems of using ballistic rockets in the development of carrier rockets for space objects in the USA. G. V. Skvortsov reported on the development of liquid fuel rocket engines in the USA in 1954-1958.

All reports given at this session were published in a collection of reports for the scientific conference of graduate students and young scientific co-workers of the Institute of the History of Science and Technology AN SSSR (Moscow, VINITI, 1965).

At the 72nd session of the section on March 1, 1965, A. P. Smolin gave a scientific and technical review of foreign literature on problems of the history of aviation, rocket technology, and astronautics. K. I. Trunov discussed V. K. Fedorov's rocket aircraft.

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The 73rd session of the section on March 22, 1965 was devoted to the 140th Birthday Anniversary of A. F. Mozhaitskiy; Candidate of Technical Sciences, V. B. Shavrov reported on the scientific and technical creativity of the inventor.

Yu. V. Biryukov gave a survey of reports of the First All-Union Conference on the use of rocket craft for investigating the stratosphere, which was held in Moscow in 1935.

On April 19, 1965 the 74th session of the section was devoted to the role of V. I. Lenin in establishing and developing Soviet aviation science and technology, at which Hero of the Soviet Union, Candidate of Military Sciences, Colonel L. M. Shishov gave a report.

A. T. Skripkin, director of the Kaluga State Museum of K. E. Tsiolkovskiy, told about the course of construction of a new museum building and the state of works on preparing new exhibits and displays.

The 75th session of the section, held on May 19, 1965, was devoted to the 60th Birthday Anniversary of A. A. Shternfel'd. Leading scientists of the Soviet Union gave speeches at the session, and greetings from individuals and members of various organizations and cities of the Soviet Union and other countries were publicly announced. The question of awarding A. A. Shternfel'd the honorary rank of Doctor of Technical Sciences and the title of Honored Scientist and Technologist was discussed.

The 76th session of the section was held on October 18, 1965. The "Outlines of the History of Technology in the USSR," prepared by a team of authors under the supervision of general aviation designer Academician A. N. Tupolev, was discussed.

On November 15, 1965 the 77th session of the section was held. V. P. Razzhivin reported on the development of dirigible construction abroad. Representatives of the Leningrad Community Design Department of Aeronautics (chief of the department, A. N. Dmitriyev and Candidate of Military Sciences N. A. Brusentsov) gave brief reports on the technical and economic grounds for dirigible construction in the USSR. Prof. A. G. Vorob'yev (Leningrad) discussed the prospects of development of dirigible construction.

At the 78th session of the section, December 6, 1965, V. I. Belolipetskiy reported on the initial period of development of the mechanics of small-thrust space flight. The reporter told about the development of scientific and technical ideas leading to the logical construction of so-called electric rocket engine systems and the formation of a new branch of science, mechanics of small-thrust space flight. A. A. Kosmodem'yanskiy, Doctor of Physical and Mathematical Sciences, Prof. I. A. Merkulov, and others, participated in the discussions, they supported and approved the conduction of further investigations in this area. /49

Memorial dates in the history of aviation and astronautics for 1966 were examined and approved at the session.

V. N. Sokol'skiy, Candidate of Technical Sciences and a member of the International Committee on the History of Rocket Technology and Astronautics of the International Academy of Astronautics, discussed a meeting of this committee held in Athens during the 16th International Astronautical Congress (September 12-18, 1965). He reported on international scientific relations of Soviet historians of aviation and astronautics.

V. I. Belolipetskiy

The Leningrad Branch of the Section of the History of Aviation and Astronautics entered the 8th year of its existence in February 1966. On January 1, 1966 the section had 80 members, including 8 professors, 20 science candidates, and 3 lecturers. Of the remaining members 90% have very specialized aeronautical education.

At present the work of the section is directed by a department staffed by: P. P. Kvade (Chairman), I. Ya. Shatoba, F. G. Popov, V. L. Korvin, I. I. Smaga, I. F. Fanichkin, and V. S. Mitin.

In 1965 eight sessions were held at which 12 reports and communications were given. On January 26, 1965 Candidate of Technical Sciences, G. N. Kopylov's report "Historical Development of the Theory of Propeller Aerodynamics" was presented. At the same session G. T. Chernenko's "The Value of the Journal 'Balloonist' in the Development of Soviet Aviation" was read. It concerned the 85th anniversary of the publication of the first issue of the Journal "Balloonist."

Candidate of Technical Sciences, A. A. Kudinov's "Historical Development of Aircraft Designs" was heard on March 26. A short talk by V. L. Korvin on the "140th Birthday Anniversary of A. F. Mozhayskiy" was given.

The report of Candidate of Technical Sciences V. G. Shakhverdov "Modern Aviation Engines" was presented on April 23, a scientific film on aviation engines was shown at the same time. At this session were heard the communications of I. F. Fanichkin and K. D. Il'inskiy on meetings with V. I. Lenin, in connection with his 95th anniversary. K. D. Il'inskiy reported on V. I. Lenin's speech to workers of the aviation plant at N. Village at Villa Rode, and I. F. Fanichkin on a meeting at the Mendel'son Plant in Moscow on August 30, 1918. /50

On May 6, 1965 a celebration session of the section where the enlistment of the aviation community of Leningrad was organized in the large conference hall of the Leningrad Branch of the Academy of Sciences SSSR in connection with the 20th Anniversary of the victory over Fascist Germany. The chief marshal of aviation, twice Hero of the Soviet Union A. A. Novikov gave the report "Soviet Aviation in the Second World War" at the celebration assembly.

The report of Candidate of Technical Sciences V. B. Shavrov "Aircraft Designed by P. O. Sukhiy (in connection with the 70th anniversary of P. O. Sukhiy)" was given on May 21, 1965. This report was richly illustrated with photographs, designs, etc. It caused numerous questions on the part of the members of the section and lively interest of the audience.

The report of Doctor of Medical Sciences Sergeyev on the topic "Urgent Problems of Aviation Medicine" was presented on October 8, 1965. The report was made in a historical connection, and the development of aviation medicine from the end of the 19th century to our day was shown. The peculiarities of aviation medicine and its value for space medicine were clearly emphasized.

I. Ya. Shatoba's communication "Thirty Years Since the Death of K. E. Tsiolkovskiy" was presented at this session.

The report of engineer, deputy chairman of the Community Design Department of Aeronautics (OKBV), N. A. Brusentsev on the topic "Prospects of Dirigibles in the Age of Jet Aviation and Astronautics" was presented on October 29, 1965.

The report of Candidate of Technical Sciences A. G. Bedunkovich "Transport Aviation at a New Stage" was presented on December 26, 1965. On the basis of its content this report could be called: "Historical development of airdrome-free aviation." The report of Comrade Bedunkovich was well illustrated with photographs and diagrams, and evoked many questions.

Along with reports and communications, the members of the section, in 1965, prepared manuscripts on the following topics:

S. M. Yakovlav: "Historico-Biographic Outlines on the Life and Activity of V. A. Slesarev."

N. S. Trukhnanov: V. V. Kuznetsov, "Outstanding Russian Balloonist, Meteorologist, and Aerologist."

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M. N. Prashchenok: "Historico-Biographic Outline on the Life and Activity of Ya. M. Gakkel'."

K. N. Zatonskiy: "Military Use of Bomber Aviation for Solving Strategic, Military Problems of the First and Second World Wars."

Many members of the section are working on personal recollections and biographical outlines of outstanding personalities in aviation.

I. Ya. Shatoba

At the Ukraine Branch of the Section of the History of Aviation and Astronautics there were 17 sessions between January 1964 and October 1965, at which the following reports and communications were heard and discussed:

Goryainov, P. V.: "Radar in the Service of the Air Force."

Yefremov, K. V.: "Participation of the Third Aviation Fleet in the Revolutionary Events of 1917 in Kiev" (personal recollections).

Karatsuba, S. I.: "Aircraft of the Kiev Aviation Designer A. D. Karpeka." (The sister of Karpeka, Ol'ga Danilova, was present at the session and gave a speech).

Kochegura, M. A.: "VTOL Aircraft."

Kochegura, M. A.: "80th Birthday Anniversary of Scientist V. A. Slesarev."

Kochegura, M. A.: "Supersonic Transport Aircraft."

Kochegura, M. A. and Ye. V. Koroleva: "75th Birthday Anniversary of the Renown Russian Aviation Designer I. I. Sikorskiy."

Kochegura, M. A. and S. A. Sobolev: "80th Anniversary of the Tests of A. F. Mozhayskiy's Airplane."

Koroleva, Ye. V.: "Information on the Second Plenum of the Soviet National Committee of Historians of Science and Technology held on May 25-28, 1965 at Moscow."

Kropivnitskiy, L. P.: "Aviation Workshops in the Village of Chervonnyy."

Laponogov, I. S.: "60th Birthday Anniversary of Valeriy Chkalov."

Laponogov, I. S.: "First Kiev Airfield."

Laponogov, I. S.: "50th Anniversary of P. N. Nesterov's Air Ram." (The daughter of Nesterov, Margarita Petrovna, was present at the session and gave a speech.)

Dyakhovetskiy, M. B.: "The Il'ich Squadron."

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Sobolev, S. A.: "140th Birthday Anniversary of A. F. Mozhayskiy, the Creator of the First Russian Airplane."

Sobolev, S. A.: "Mozhayskiy and Mendeleyev."

Sofronov, N. I.: "On the Activity of the Oldest Aviation Designer of the Ukraine, S. V. Grizodubov" (in commemoration of his 80th birthday).

Tret'yakov, N. S.: "History and Progress of Aviation."

Tret'yakov, N. S.: "Certain Features in the Development of Aviation in Recent Years."

Kheyfets, L. S.: "Lenin and Aviation."

Shevchenko-Bolsunovskiy, N. S.: "Aviation in the Early Period of the Second World War."

On February 26 the section together with the Kiev Institute of Civil Aviation and the Administration of Civil Aviation held a jubilee session devoted to the memory of the Ukrainian aircraft designer Konstantin Alekseyevich Kalinin in connection with his 75th birthday. A pupil of K. A. Kalinin, Hero of the Soviet Union, engineer-pilot, A. N. Gratsianskiy gave the opening address. Pupils and comrades of the designer presented their recollections.

On the initiative of section member, Mikhail Osipovich Kovan' the Khar'kov community honored its 80-year-old fellow citizen, designer S. V. Grizodubov on Air Force Day in 1964. He was awarded the Diploma of the Presidium of the Supreme Council of the UkrSSR.

Khar'kov also marked the 130th anniversary of the first balloonist of the Ukraine, M. T. Lavrent'yev. The city executive committee passed a resolution to establish a memorial plaque in honor of M. T. Lavrent'yev in Khar'kov.

Based on the scenario described by Kovan', the Khar'kov television studio prepared and showed viewers the performance of balloonist M. T. Lavrent'yev.

M. O. Kovan' spent considerable effort on the organization of a section on the history of aeronautics and aviation of local lore at the Khar'kov Museum. The exhibit in this section shows a model of S. V. Grizodubov's first airplane which the designer made by hand.

In recent years the section has increased its work on propagandizing the history of aviation. For this purpose Comrades Kochegura, Lyakhovetskiy, Laponogov, Shevchenko-Bolsunovskiy, and especially Sobolev and Kovan' have presented reports and held discussions at enterprises and organizations. Sobolev presented the report **"From Mozhayskiy to Gagarin" at enterprises**. In 1964, Kovan', as a nonstaff lecturer at the planetarium, went to the collective farms of the Khar'kov region where he gave 47 reports on balloonist M. T. Lavrent'yev, and in the same year he gave 26 lectures on **"From the Balloon to Space Flight"** at collective farms of the Galakleyevskiy region.

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Members of the section have presented articles for the local, republic, and union press. For example, the newspaper "Vechirniy Kiiiv" published:

Lapogonov, I. S.: "The Aerodrome that Went Down in History." August 12, 1963.

"Fearless Falcon." December 16, 1964.

"Museum of Aviation History." January 26, 1965.

Lyakhovetskiy, M. B.: "First Time in Service." September 26, 1963.

"First Regulars." May 25, 1964.

"Powerful Wings." April 18, 1964.

"Commander of the Anthem." August 13, 1965.

The newspaper "Sotsialistichna kharkivshchina" printed three articles by M. O. Kovan': On Grizodubov, Utochkin, and on Lectures at Collective Farms.

The journal "Kryl'ya rodiny" contained an article by I. S. Lapogonov "Veteran of Two Wars" concerning the old pilot T. S. Shelukhin (No. 7, 1965).

The L'vov journal "Zhovten'" printed V. A. Zamlinskiy's outline "50 Years Before the Start" (about F. R. Geshvend) (Zhovten', No. 4, 1965).

The newspaper "Aviator" of the Kiev Institute of Civil Aviation has become a permanent tribune on aviation history for members of the section. Not only hundreds of students and teachers read it, but the newspaper is also distributed to libraries of civil aviation units of the Soviet Union. The newspaper "Aviator" printed the following articles:

Kochegura, M. A.: "A Falsification from the History of Aeronautics" (No. 7, 1964).

Kratsianskiy, A. N.: "Talented Aircraft Designer" (No. 7, 1964) (about K. A. Kalinin).

Kheyfets, L. S.: "Pages of History." (From the history of the Kiev Aviation Institute) (Nos. 4, 8, 9, 12, 1965).

Sobolev, S. A.: "Mozhayskiy in the Ukraine" (No. 10, 1965).

Karatsuba, S. I.: "At the Dawn of Soviet Gliding" (No. 13, 1965).

Koroleva, Ye. V.: "First Flights" -- Chapter from the manuscript on M. N. Yefimov. (Nos. 19, 21, 22, 24, 1965).

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Laponogov, I. S.: "Kiev Airdromes." (Nos. 29, 30, 1965) and others.

The journal "Narisi z Istorii tekhniki i trirodoznavstva" of the Ukraine Branch of the Soviet National Union of Historians of Science and Technology has regularly published, beginning with the third issue, articles from aviation history:

Issue 3. Lyakhovetskiy, M. B.: "Talented Ukrainian Craftsmen" (about I. S. Tereverko).

Issue 4. "80th Anniversary of Honored Pilot of the USSR B. I. Rossinskiy -- His Memoirs." 1964.

Dobrov, G. M.: "Documents from the History of Soviet Aviation."

Koroleva, Ye. V.: "New Material on the Life and Activity of the Russian Pilot M. N. Yefimov."

Denisenko, V. I.: "The Airplane 'Chur' Among the First."

Kochegura, M. A.: "On the Work of the Section of the History of Aviation and Astronautics."

Issue 5. Karatsuba, S. I.: "Gliders of the Kiev Polytechnic Institute." 1965.

At present the section is vigorously working on preparing the manuscript "Development of Aviation in the Ukraine." The materials submitted to the editorial board by authors are being examined and discussed at the section.

Furthermore, the section is solving problems of establishing an obelisk to P. N. Nesterov and the organization of an aviation museum in Kiev.

Ye. V. Koroleva

## CONFERENCE OF HISTORIANS OF ASTRONAUTICS

The routine session of the International Committee on the History of Rocket Technology and Astronautics was held in Athens in September 1965. This committee, created in 1963 within the frameworks of the International Academy of Astronautics, has set out to coordinate and unify the efforts of scientists studying the history of these fields of knowledge.

Its staff is presently made up by representatives of eight countries: A. Haily and L. Shepard (England), T. Tabanera (Argentina), V. Sokol'skiy (USSR), /55 F. Malin and E. Emme (USA), S. Dolfus (France), I. Zenger-Bredt (West Germany), R. Pecek (Czechoslovakia), W. Von Euler (Sweden). The president of the International Academy of Astronautics, K. Draper and assistant director of the American National Museum of Aeronautics and Astronautics, F. Durant also participated in the work of the Athens session of the committee.

At the first meeting the committee discussed problems of the goals and tasks of historical research in the area of rocket technology and astronautics and the structure and program of work of the committee, and conducted a preliminary discussion of the problem of division into periods and passed a number of recommendations onto the president of the Academy.

After an exchange of opinions, the members of the committee concluded that at present, of greatest interest for the International Academy of Astronautics and for a broad scientific community are investigations in such areas as:

- a) history of rocket technology
- b) history of astronautics
- c) history of space research
- d) history of equipment for controlling space vehicles
- e) history of means of communication in space
- f) history of bioastronautics

It was also decided to institute an annual Th. Von Karman Prize (first president of the International Academy of Astronautics) for best work in the history of rocket technology and astronautics.

Because at present national committees uniting historians of rocket technology exist only in two countries, in the USSR (Chairman of the committee A. A. Blagonravov, deputy chairman V. N. Sokol'skiy) and in the USA (Chairman E. M. Emme, assistant chairman F. Durant), the committee resolved to place before the International Astronautical Federation the problem of creating national historical committees in all countries belonging to the Federation.

The second meeting of the committee began with informational reports of members of the committee on research into the history of rocket technology and astronautics carried out in countries represented by them. As was already noted above, in most countries historians of aviation and astronautics have so far /56 not been unified, and work largely independently of one another.

In this connection the members of the committee showed considerable interest in the problem of organizing research into the history of rocket technology and

astronautics in the USSR and USA. Without dwelling on the work of the section of the History of Aviation and Astronautics of the Soviet National Union of Historians of Science and Technology (which has been repeatedly elucidated in our historico-scientific publications), we will present certain information on the organization of research into the history of these areas in the USA.

In the USA the first professional organization interested in the history of astronautics was the National Space Club which instituted, in 1959, the annual Goddard competition for the best work on the history of rocket technology and astronautics in order to stimulate the development of this area of knowledge in the USA. In 1962 the American Association for Scientific Progress and the Society of Technological Historians held a joint conference devoted to the history of rocket technology in the USA, in which, along with technological historians, participated G. E. Pendrey, W. R. Dornberger, J. P. Hagen, etc. In 1964 a Historical Committee was created, also under the American Institute of Aeronautics and Astronautics. Furthermore, individual research institutes and universities devote considerable attention to the development of the history of rocket technology and astronautics. It suffices to say that at a number of American universities a special course is given on the history of space flight. The Smithsonian Institute in Washington performs considerable research work in the area of the history of astronautics. Finally, quite recently it was deemed necessary to create a Historical Committee under the National Aeronautics and Space Administration (NASA).

Further, the committee discussed the problem of exchanging publications and information on works carried out in different countries and examining the plan of conferences and symposia in future years. It was resolved to hold, in 1967, an International Symposium on the topic "The Role of Pioneers of Rocket Technology in the Development of Astronautics."

The past session of the committee showed that in recent years interest in problems of the history of rocket technology and astronautics has grown appreciably in many countries. This challenges researchers working in this area with new, considerably higher requirements.

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#### REVIEWS AND BIBLIOGRAPHY

A. M. IZAKSON. SOVIET HELICOPTER CONSTRUCTION.  
Izd-vo Mashinostroyeniye. Moscow, 1965.

Today, when helicopters have gained general recognition and have become a part of life, the appearance of a serious book devoted to the history of helicopter construction must be acknowledged as very timely and welcomed in every possible way. It is quite natural that Aleksandr Mikhaylovich Izakson, the elder figure in Soviet helicopter construction, should turn to this difficult topic.

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Unlike his earlier literary works in this area\* devoted mainly to foreign helicopter construction, the new book is a history of Soviet helicopter construction.

The book gives a thorough description of all works in the area of helicopters carried out in Russia from the time of M. V. Lomonosov until the October Revolution in 1917, gives a condensed version of all scientific works on propellers and helicopters by N. Ye. Zhukovskiy, and, finally, elucidates with exhaustive thoroughness the works of B. N. Yur'yev, a leading figure in Soviet helicopter construction.

The bulk of the book is devoted to works on helicopters in the Soviet Union. The periods between 1925 and 1937, the periods of the birth of Soviet helicopter construction, development of the first Soviet helicopters, and the first major progress in solving this problem, is elucidated quite thoroughly.

Most of those now working in various areas of Soviet helicopter construction have been engaged in this work during the past decade. For the most part these are young people.

These workers know little about the history and birth of Soviet helicopter construction, have vague ideas about the first Soviet helicopters, about autogiro construction, about the mutual influence of these two related branches of aviation.

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For them this section of the book will be very useful and interesting since it is written with painstaking completeness, clarity, and with great fervor. And it could not be otherwise since the author of the book A. M. Izakson was an active participant of work on helicopters of that period, having headed for many years in the USSR, the design and research organization on helicopters and autogiros which brought together enthusiasts, talented people from among young engineers, and party members since 1917-1920, who passed through the harsh school of the Civil War, and the best representatives of nonparty specialists of the older generation.

Having undertaken the task of encompassing an appreciable period of time and of bringing the account up-to-date, the author of the book should have inevitably encountered a number of specific difficulties, since works of the recent past and contemporary work sometimes are difficult to objectively evaluate completely and sufficiently.

A. M. Izakson coped well with these difficulties, knowing how to evaluate quite objectively the quality and value of a number of constructed craft, the activity of design organizations, and the role of numerous workers in helicopter construction.

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\*Izakson, A. M.: Helicopters (Gelikoptery), Izd. GNTI, 1931 and Izakson, A. M.: Helicopters (Gelikoptery), Izd. Oborongiza, 1947.

Along with a detailed elucidation of the history of Soviet helicopter construction, the book gives an abbreviated review of the state of foreign helicopter construction at each historical stage. This is quite regular and proper since it gives the reader the opportunity to get a broader idea about the comparative level of world and Soviet helicopter construction.

People advance technology. It is natural that in a work on the history of the development of a particular branch of technology, the activity of people, the creators of this technology, should be sufficiently reflected and an evaluation of their constructive role at decisive stages be given.

A. M. Izakson quite scrupulously notes in his book the large number of participants who worked on the development of helicopters and autogiros, without limiting himself to mentioning only the main designers or principal directors, but naming also very many designers, engineers, calculators, scientific workers, test pilots, and a number of others who, while not now occupying any administrative posts, creatively approached their work, demonstrated much valuable initiative, and went about their work with joy and enthusiasm.

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Undoubtedly, their extensive auxiliary material in the appendix to the book in the form of statistical tables and the quite complete and carefully selected list of recommended literature will be of great benefit to the reader.

The previous books of A. M. Izakson found many readers among aviation workers interested in helicopters. For many, especially among youthful students, they have been a reference book for a long time.

Without a doubt the new book by A. M. Izakson will also be favorably received, will be highly evaluated, and will be a valuable contribution of its author to the future progress and blossoming of Soviet helicopter construction.

V. B. Shavrov

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